

HITOMI

THE HITOMI STEP-BY-STEP ANALYSIS GUIDE

Applicable to Hitomi Software/Caldb version 4, Data Processing Run 2

Date: 22 September 2016

Version 4

X-ray Astrophysics Laboratory (NASA/Goddard Space Flight Center)

and the

Institute of Space and Astronautical Science (ISAS/JAXA)

Table of Contents

Table of Contents.....	2
Notes on this version of the guide and differences from previous version	5
Data Sequence log	5
Software and CALDB Files.....	6
Software.....	6
CALDB.....	6
Summary of Tasks Run	7
Randomization.....	9
G21.5-0.9	9
Data description.....	9
Additional Files.....	11
Note on sequences	12
Non-Instrument Specific Processing.....	12
ahcalctime	12
100050020	12
ahpipeline	12
Instrument Specific Reprocessing.....	13
100050020	13
HXI.....	13
SGD.....	13
SXI.....	14
SXS.....	15
Extracting Products.....	16
100050020	16
HXI.....	16
SGD.....	18
SXI.....	20
SXS.....	23
100050010, 100050020, 100050030, 100050040 COMBINED.....	26
HXI.....	26
SGD.....	31
SXI.....	34
SXS.....	34
Generating Exposure Map, RMF, and ARF	35
100050020	35
HXI.....	35
SGD.....	38
SXI.....	38
SXS.....	41
100050010, 100050020, 100050030, 100050040 COMBINED.....	42
HXI.....	42
SGD.....	44
SXI.....	45

SXS.....	51
Spectral Fittting.....	52
Notes	52
HXI.....	52
SGD.....	55
SXI.....	56
SXS.....	58
JOINT FITS	59
Perseus Cluster.....	65
Data description.....	65
Additional Files.....	66
Note on sequences	66
Non-Instrument Specific Processing.....	67
ahcalctime.....	67
100040030	67
ahpipeline	67
100040060	67
Instrument Specific Reprocessing.....	67
100040030	67
SXS.....	67
100040010	68
SXS.....	68
Extracting Products.....	68
100040030	69
SXS.....	69
100040060	71
SXI.....	71
SXS.....	73
100040020, 100040030, 100040040, 100040050 combined	75
SXS.....	75
Generating Exposure Map, RMF, and ARF	75
100040030	76
SXS.....	76
100040060	77
SXI.....	77
SXS.....	80
100040020, 100040030, 100040040, 100040050 combined	80
Spectral Fittting.....	82
Notes	82
SXS.....	83
Crab Nebula	87
Data description.....	87
Additional Files.....	89
Note on this sequence.....	89
Non-Instrument Specific Processing.....	90
ahcalctime.....	90

100044010	90
ahpipeline	90
Instrument Specific Reprocessing.....	90
100044010	90
Extracting Products.....	90
100044010	90
HXI.....	90
SGD.....	93
SXI.....	95
SXS.....	97
Generating Exposure Map, RMF, and ARF.....	99
100044010	99
HXI.....	99
SGD.....	101
SXI.....	102
SXS.....	103
Spectral Fittting.....	105
Notes	105
HXI.....	105
SGD.....	106
SXI.....	107
SXS.....	109
JOINT Spectra	110
N132D.....	115
Note on sequences.....	117
Instrument Specific Reprocessing.....	117
100041010	117
SXS.....	117
100041020	118
SXI.....	118
Extracting Products.....	118
100041010	118
SXS.....	118
100041020	119
SXI.....	119
Generating Exposure Map, RMF, and ARF.....	122
100041010	122
SXS.....	122
100041020	122
SXI.....	122

Notes on this version of the guide and differences from previous version

This version of the step-by-step guide is applicable to the Hitomi archived data, software, and calibration available to the Hitomi SWG as of 2016 Sepetember 22, i.e. second complete release of the data, and Hitomi v4 software and CALDB. As in previous versions the procedures follow the sequence used in earlier training sessions. For each object, the steps are grouped into (1) reprocessing, (2) product extraction, (3) response generation, and (4) spectral fitting categories; and, divided by instrument within each of these groups for all relevant detectors. Since the previous version of this guide some software tasks and selection criteria contained in CALDB have been revised; HXI and SXI MZDYE data are particularly affected. There are also new procedures for deriving combined SXI data products, and SXI background spectra, which are include in the section on generating exposure map and response files. This version includes, for the first time, instructions for the Crab Nebula observation, and SXI observations of the Perseus Cluster. Also, region files are adjusted to account for updated attitude files.

Data Sequence log

SEQ_ID	Target	INSTRUMENTS ON	POINTING
100050010	G21.5-0.9	SXS, SXI, HXI1, HXI2	ON-AXIS
100050020	G21.5-0.9	SXS, SXI, HXI1, HXI2, SGD1	ON-AXIS
100050030	G21.5-0.9	SXS, SXI, HXI1, HXI2, SGD1	ON-AXIS
100050040	G21.5-0.9	SXS, SXI, HXI1, HXI2, SGD1	ON-AXIS
100045010	Crab	SXS, SXI, HXI1, HXI2, SGD1, SGD2	ON-AXIS
100040030	Perseus	SXS	~1 ARCMIN OFF CENTER
100040040	Perseus	SXS	~1 ARCMIN OFF CENTER
100040050	Perseus	SXS	~1 ARCMIN OFF CENTER
100040060	Perseus	SXS, SXI	~ON CENTER
100040010	Perseus_core	SXS	~3.5 ARCMIN OFF CENTER
100040020	Perseus_core adjustment	SXS	~3.5 ARCMIN OFF CENTER
100041010	N132D	SXS, SXI	OFF-CENTER, SXI GAP
100041020	N132D	SXS, SXI	OFF-CENTER, SXI GAP
100042010	IGR J16318-4848	SXS, SXI	OFF-CENTER
100042020	IGR J16318-4848	SXS, SXI, HXI1	OFF-CENTER
100042030	IGR J16318-4848	SXS, SXI, HXI1	OFF-CENTER
100042040	IGR J16318-4848	SXS, SXI, HXI1	OFF-CENTER
100043010	RXJ1856.5-3754	SXS, SXI, HXI1, HXI2, SGD1	OFF-CENTER, NO SXS
100043020	RXJ1856.5-3754	SXS, SXI, HXI1, HXI2, SGD1	OFF-CENTER, NO SXS
100043030	RXJ1856.5-3754	SXS, SXI, HXI1,	OFF-CENTER, NO SXS

		HXI2, SGD1	
100043040	RXJ1856.5-3754	SXS, SXI, HXI1, HXI2, SGD1	OFF-CENTER, NO SXS
100043050	RXJ1856.5-3754	SXS, SXI, HXI1, HXI2, SGD1, SGD2	OFF-CENTER, NO SXS
100043060	RXJ1856.5-3754	SXS, SXI, HXI1, HXI2, SGD1, SGD2	OFF-CENTER, NO SXS
100045010	Mrk205		

NOTE: “INSTRUMENT ON” excludes HXI and SGD DATAMODE=STANDBY data.

Software and CALDB Files

File	Description
alias_config.fits	CALDB supporting file
caldb.config	CALDB supporting file
caldb_hitomi_20160812all.tar.gz	CALDB data files
Hitomi_22Sep2016_V004-src.tgz	Hitomi software release

Software

Directions for building and installing the HITOMI package as a standalone.

a) untar the software tar file in a directory mydir

```
cd /full-path/mydir
tar -zxf Hitomi_22Sep2016_V004-src.tgz
```

b) build/install

```
cd /full-path/mydir/Hitomi_22Sep2016_V004/BUILD_DIR
```

To build and install the code use the instructions you find under step 3 accordingly to the operating system in the following page:

<https://heasarc.gsfc.nasa.gov/docs/software/lheasoft/download.html>

d) Set up environment

```
setenv HEADAS /full-path/mydir/Hitomi_22Sep2016_V004/operating-system
source $HEADAS/headas-init.csh
```

CALDB

Directions for installing the latest HITOMI CALDB as a standalone.

Untar in a directory “/full-path/caldbdir” and copy the caldb.config and alias_caldb.fits files into there.

```

cd full-path/caldbdir
tar -xzvf caldb_hitomi_20160812all.tar.gz
cp /location_of/caldb.config ./
cp /location_of/caldb.fits ./

setenv CALDB /full-path/caldbdir/caldb
setenv CALDBCONFIG /full-path/caldbdir/caldb/caldb.config
setenv CALDBALIAS /full-path/caldbdir/caldb/alias_caldb.fits

```

Summary of Tasks Run

	description	input	output	CALDB
ahcalctime	recalculate time	tim file gen hk <inst>-hk <inst>-uf.evt sxs lost GTI	tim file gen hk <inst>-hk <inst>-uf.evt sxs lost GTI	frqtemfile coeftime coldeffile delayfile offsetfile leapsecfile
ahpipeline	reprocess all events	indir outdir steminputs stemoutputs instrument entry_stage exit_stage verify_input		
hxipipeline	reprocess hxi events	attitude orbit obsgti mkf ehk hxi-hk hxi-uf hxi-cams hxi-pseudo-uf	hxi-uf hxi-ufa hxi-cl hxi-pseudo-cl hxi-delta-attitude	hxi teldef cams teldef cams temperature selectfile remapfile gainfile badpixfile fluorefile enecutfile
sgdpipeline	reprocess sgd events	attitude orbit obsgti mkf ehk sgd-hk sgd-uf sgd-pseudo-uf	sgd-uf sgd-ufa sgd-cl sgd-pseudo-cl	remapfile gainfile badpixfile fluorefile probseqfile probfovfile selectfile
sxipipeline	reprocess sxi events	attitude orbit obsgti mkf ehk sxi-hk sxi-uf sxi-hpix sxi-exp	sxi-uf sxi-cl sxi-fpix sxi-bimg sxi-mode-gti sxi-seg-gti	sxs teldef selectfile badpixfile maskfile vtevbodddfile ctifile chtrailfile spthfile gainfile patternfile

sxspipeline	reprocess sxs events	attitude orbit obsgti mkf ehk sxs-hk sxs-ac sxs-pix-uf sxs-el-gti	sxs-hk sxs-uf sxs-ac sxs-pix-cl mxs-gti sxs-ghf	sxs teldef selectfile antico gain pixel wiring map pixel gain antico gain calline profiles delay file time coefficients pulse file
hxisgddtime	correct light curve and spectrum for dead time	pseudo-event file Light curve Spectrum GTI file	corrected light curve corrected spectrum	none
barycen	correct time for Solar System barycenter	event file or light curve orbit	corrected event file or light curve	none
ahgtigen	create or combine GTI	ehk or mkf file or list of GTI	single or merged GTI	leapsecfile
ahscreen	create or combine GTI	event file GTI expression	screened event file	leapsecfile selectfile
sxsregext	extract SXS data products	sxs-pix-cl region (SKY/DET) grade selection ehk	image, lightcurve, spectrum exposure map DET region	teldef instrument map qefile contamfile obffile fwfile gvfile
ahexpmap	generate exposure map	ehk file GTI file bimg file (SXI) pixgtifile (SXI/S) range-theta num-phi	exposure map file	instmap
ahexpmap	generate flat field (SXI/S)	ehk file GTI file bimg file (SXI) pixgtifile range-theta num-phi	efficiency map file	instmap qefile contamfile vigfile gvfile (SXS) fwfile (SXS) obffile (SXS)
sxsmkrmf	generate SXS RMF file	sxs-pix-cl region (DET) grade selection	RMF file	teldef line-spread function
aharfgen	generate ARF file	exposure map RMF delta-att file (HXI) cams-offset (HXI) region (DET) source distribution energy range	ARF (SXI/S) or RSP file (HXI)	teldef qefile contamfile (SXI/S) gvfile (SXS) fwfile (SXS) obffile (SXS) on-axis ARF (fine and coarse)

				mirror description obstructions frontside refl/trans backside refl/trans pre-coll refl/trans scattering
hxirspeffimg	generate flat field (HXI)	exposure map delta-attitude cams-offset energy range raytrace file	efficiency map file	teldef qefile rmfffile vigfile on-axis ARF (fine and coarse) mirror description obstructions frontside refl/trans backside refl/trans pre-coll refl/trans scatteringnstmap

Randomization

In the tool command examples in this document, the randomization seed is always set to one number, `seed=7`. This is just for testing, to ensure that ahpipeline and the instrument pipelines get the same results. In practice, a user would want a random seed taken from the system time, i.e. `seed=0`.

G21.5-0.9

Data description

Table 3a	100050010	100050020
GEN-HK	ah100050010gen_a0.hk1.gz	ah100050020gen_a0.hk1.gz
TIM	ah100050010.tim.gz	ah100050020.tim.gz
ATTITUDE	ah100050010.att.gz	ah100050020.att.gz
ORBIT	ah100050010.orb.gz	ah100050020.orb.gz
OBSGTI	ah100050010_gen.gti.gz	ah100050020_gen.gti.gz
MKF	ah100050010.mkf.gz	ah100050020.mkf.gz
EHK	ah100050010.ehk.gz	ah100050020.ehk.gz
EHK2	ah100050010.ehk2.gz	ah100050020.ehk2.gz
HXI1 HK	ah100050010hx1_a0.hk.gz	ah100050020hx1_a0.hk.gz
HXI2 HK	ah100050010hx2_a0.hk.gz	ah100050020hx2_a0.hk.gz
HXI DELTA-ATT	ah100050010hx1.att.gz	ah100050020hx1.att.gz
HXI DELTA-ATT	ah100050010hx2.att.gz	ah100050020hx2.att.gz
HXI1 CAMS	ah100050010hx1_cms.fits.gz	ah100050020hx1_cms.fits.gz
HXI2 CAMS	ah100050010hx2_cms.fits.gz	ah100050020hx2_cms.fits.gz
HXI1 SFF	ah100050010hx1_p0camrec_uf.evt.gz	ah100050020hx1_p0camrec_uf.evt.gz
HXI2 SFF	ah100050010hx2_p0camrec_uf.evt.gz	ah100050020hx2_p0camrec_uf.evt.gz
HXI1 SFFa	ah100050010hx1_p0camrec_ufa.evt.gz	ah100050020hx1_p0camrec_ufa.evt.gz
HXI2 SFFa	ah100050010hx2_p0camrec_ufa.evt.gz	ah100050020hx2_p0camrec_ufa.evt.gz
HXI TEL	ah100050010hx1_tel.gti.gz	ah100050020hx1_tel.gti.gz
HXI1 PSEUDO	ah100050010hx1_p0camrecpse_cl.evt.gz	ah100050020hx1_p0camrecpse_cl.evt.gz
HXI2 PSEUDO	ah100050010hx2_p0camrecpse_cl.evt.gz	ah100050020hx2_p0camrecpse_cl.evt.gz
HXI1 EVT CL	ah100050010hx1_p0camrec_cl.evt.gz	ah100050020hx1_p0camrec_cl.evt.gz
HXI2 EVT CL	ah100050010hx2_p0camrec_cl.evt.gz	ah100050020hx2_p0camrec_cl.evt.gz

SGD1 HK	ah100050010sg1_a0.hk.gz	ah100050020sg1_a0.hk.gz
SGD2 HK	ah100050010sg2_a0.hk.gz	ah100050020sg2_a0.hk.gz
SGD1 SFF		ah100050020sg1_p0cc1rec_uf.evt.gz ah100050020sg1_p0cc2rec_uf.evt.gz ah100050020sg1_p0cc3rec_uf.evt.gz
SGD1 SFFa		ah100050020sg1_p0cc1rec_ufa.evt.gz ah100050020sg1_p0cc2rec_ufa.evt.gz ah100050020sg1_p0cc3rec_ufa.evt.gz
SGD TEL		ah100050020sg1_tel.gti.gz
SGD1 PSEUDO		ah100050020sg1_p0cc1recpse_cl.evt.gz ah100050020sg1_p0cc2recpse_cl.evt.gz ah100050020sg1_p0cc3recpse_cl.evt.gz
SGD1 EVT CL		ah100050020sg1_p0cc1rec_cl.evt.gz ah100050020sg1_p0cc2rec_cl.evt.gz ah100050020sg1_p0cc3rec_cl.evt.gz
SXI EVT UF	ah100050010sxi_p0100004b0_uf.evt.gz	ah100050020sxi_p0100004b0_uf.evt.gz
SXI MZDYE EVT UF	ah100050010sxi_p0100004b1_uf.evt.gz	ah100050020sxi_p0100004b1_uf.evt.gz
SXI HOTPIX	ah100050010sxi_a0100004b0.hpix.gz	ah100050040sxi_a0100004b0.hpix.gz
SXI MZDYE HOTPIX	ah100050010sxi_a0100004b1.hpix.gz	ah100050040sxi_a0100004b1.hpix.gz
SXI FLICKPIX	ah100050010sxi_a0100000b0.fpix.gz	ah100050040sxi_a0100000b0.fpix.gz
SXI MZDYE FLICKPIX	ah100050010sxi_a0100000b1.fpix.gz	ah100050040sxi_a0100000b1.fpix.gz
SXI BAD PIXEL IMG	ah100050010sxi_p0100000b0.bimg.gz	ah100050040sxi_p0100000b0.bimg.gz
SXI MZDYE BAD PIXEL IMG	ah100050010sxi_p0100000b1.bimg.gz	ah100050040sxi_p0100000b1.bimg.gz
SXI TEL	ah100050010sxi_tel.gti.gz	ah100050040sxi_tel.gti.gz
SXI EVT CL	ah100050010sxi_p0100004b0_cl.evt.gz	ah100050040sxi_p0100004b0_cl.evt.gz
SXI MZDYE EVT CL	ah100050010sxi_p0100004b1_cl.evt.gz	ah100050040sxi_p0100004b1_cl.evt.gz
SXS HK	ah100050010sxs_a0.hk1.gz	ah100050020sxs_a0.hk1.gz
SXS ADR	ahsxs_adr.gti.gz	ahsxs_adr.gti.gz
SXS AC EVT	ah100050010sxs_a0ac_uf.evt.gz	ah100050020sxs_a0ac_uf.evt.gz
SXS PIX12 GAIN	ah100050010sxs_010_px12.ghf.gz	ah100050020sxs_010_px12.ghf.gz
SXS PIX12 EVT	ah100050010sxs_a0px12010_uf.evt.gz	ah100050020sxs_a0px12010_uf.evt.gz
SXS EL GTI	ah100050010sxs_el.gti.gz	ah100050020sxs_el.gti.gz
SXS TEL	ah100050010sxs_tel.gti.gz	ah100050020sxs_tel.gti.gz
SXS PIX GTI	ah100050010sxs_p0px1010.gti.gz	ah100050020sxs_p0px1010.gti.gz
SXS PIX EXP	ah100050010sxs_p0px1010_exp.gti.gz	ah100050020sxs_p0px1010_exp.gti.gz
SXS PIX UF	ah100050010sxs_p0px1010_uf.evt.gz	ah100050020sxs_p0px1010_uf.evt.gz
SXS PIX CL	ah100050010sxs_p0px1010_cl.evt.gz	ah100050020sxs_p0px1010_cl.evt.gz

Table 3b	100050030	100050040
GEN-HK	ah100050030gen_a0.hk1.gz	ah100050040gen_a0.hk1.gz
TIM	ah100050030.tim.gz	ah100050040.tim.gz
ATTITUDE	ah100050030.att.gz	ah100050040.att.gz
ORBIT	ah100050030.orb.gz	ah100050040.orb.gz
OBSGTI	ah100050030_gen.gti.gz	ah100050040_gen.gti.gz
MKF	ah100050030.mkf.gz	ah100050040.mkf.gz
EHK	ah100050030.ehk.gz	ah100050040.ehk.gz
EHK2	ah100050030.ehk2.gz	ah100050040.ehk2.gz
HXI1 HK	ah100050030hx1_a0.hk.gz	ah100050040hx1_a0.hk.gz
HXI2 HK	ah100050030hx2_a0.hk.gz	ah100050040hx2_a0.hk.gz
HXI DELTA-ATT	ah100050030hx2.att.gz	ah100050040hx2.att.gz
HXI1 CAMS	ah100050030hx1_cms.fits.gz	ah100050040hx1_cms.fits.gz
HXI2 CAMS	ah100050030hx2_cms.fits.gz	ah100050040hx2_cms.fits.gz
HXI1 SFFa	ah100050030hx1_p0camrec_ufa.evt.gz	ah100050040hx1_p0camrec_ufa.evt.gz
HXI2 SFFa	ah100050030hx2_p0camrec_ufa.evt.gz	ah100050040hx2_p0camrec_ufa.evt.gz
HXI1 SFF	ah100050030hx1_p0camrec_uf.evt.gz	ah100050040hx1_p0camrec_uf.evt.gz
HXI2 SFF	ah100050030hx2_p0camrec_uf.evt.gz	ah100050040hx2_p0camrec_uf.evt.gz
HXI TEL	ah100050030hxi_tel.gti.gz	ah100050040hxi_tel.gti.gz
HXI1 PSEUDO	ah100050030hx1_p0camrecpse_cl.evt.gz	ah100050040hx1_p0camrecpse_cl.evt.gz
HXI2 PSEUDO	ah100050030hx2_p0camrecpse_cl.evt.gz	ah100050040hx2_p0camrecpse_cl.evt.gz
HXI1 EVT CL	ah100050030hx1_p0camrec_cl.evt.gz	ah100050040hx1_p0camrec_cl.evt.gz
HXI2 EVT CL	ah100050030hx2_p0camrec_cl.evt.gz	ah100050040hx2_p0camrec_cl.evt.gz
SGD1 HK	ah100050030sg1_a0.hk.gz	ah100050040sg1_a0.hk.gz
SGD2 HK	ah100050030sg2_a0.hk.gz	ah100050040sg2_a0.hk.gz
SGD1 SFF	ah100050030sg1_p0cc1rec_uf.evt.gz ah100050030sg1_p0cc2rec_uf.evt.gz	ah100050040sg1_p0cc1rec_uf.evt.gz ah100050040sg1_p0cc2rec_uf.evt.gz

	ah100050030sg1_p0cc3rec_uf.evt.gz	ah100050040sg1_p0cc3rec_uf.evt.gz
SGD1 SFFa	ah100050030sg1_p0cc1rec_ufa.evt.gz ah100050030sg1_p0cc2rec_ufa.evt.gz ah100050030sg1_p0cc3rec_ufa.evt.gz	ah100050040sg1_p0cc1rec_ufa.evt.gz ah100050040sg1_p0cc2rec_ufa.evt.gz ah100050040sg1_p0cc3rec_ufa.evt.gz
SGD TEL	ah100050030sg1_tel.gti.gz	ah100050040sg1_tel.gti.gz
SGD1 PSEUDO	ah100050030sg1_p0cc1recpse_cl.evt.gz ah100050030sg1_p0cc2recpse_cl.evt.gz ah100050030sg1_p0cc3recpse_cl.evt.gz	ah100050040sg1_p0cc1recpse_cl.evt.gz ah100050040sg1_p0cc2recpse_cl.evt.gz ah100050040sg1_p0cc3recpse_cl.evt.gz
SGD1 EVT CL	ah100050030sg1_p0cc1rec_cl.evt.gz ah100050030sg1_p0cc2rec_cl.evt.gz ah100050030sg1_p0cc3rec_cl.evt.gz	ah100050040sg1_p0cc1rec_cl.evt.gz ah100050040sg1_p0cc2rec_cl.evt.gz ah100050040sg1_p0cc3rec_cl.evt.gz
SXI EVT UF	ah100050030sxi_p0100004b0_uf.evt.gz	ah100050040sxi_p0100004b0_uf.evt.gz
SXI MZDYE EVT UF	ah100050030sxi_p0100004b1_uf.evt.gz	ah100050040sxi_p0100004b1_uf.evt.gz
SXI HOTPIX	ah100050030sxi_a0100004b0.hpix.gz	ah100050040sxi_a0100004b0.hpix.gz
SXI MZDYE HOTPIX	ah100050030sxi_a0100004b1.hpix.gz	ah100050040sxi_a0100004b1.hpix.gz
SXI FLICKPIX	ah100050030sxi_a0100000b0.fpix.gz	ah100050040sxi_a0100000b0.fpix.gz
SXI MZDYE FLICKPIX	ah100050030sxi_a0100000b1.fpix.gz	ah100050040sxi_a0100000b1.fpix.gz
SXI BAD PIXEL IMG	ah100050030sxi_p0100000b0.bimg.gz	ah100050040sxi_p0100000b0.bimg.gz
SXI MZDYE BAD PIXEL IMG	ah100050030sxi_p0100000b1.bimg.gz	ah100050040sxi_p0100000b1.bimg.gz
SXI TEL	ah100050030sxi_tel.gti.gz	ah100050040sxi_tel.gti.gz
SXI EVT CL	ah100050030sxi_p0100004b0_cl.evt.gz	ah100050040sxi_p0100004b0_cl.evt.gz
SXI MZDYE EVT CL	ah100050030sxi_p0100004b1_cl.evt.gz	ah100050040sxi_p0100004b1_cl.evt.gz
SXS HK	ah100050030sxs_a0.hk1.gz	ah100050040sxs_a0.hk1.gz
SXS ADR	ahsxs_adr.gti.gz	ahsxs_adr.gti.gz
SXS AC EVT	ah100050030sxs_a0ac_uf.evt.gz	ah100050040sxs_a0ac_uf.evt.gz
SXS PIX12 GAIN	ah100050030sxs_010_px12.ghf.gz	ah100050040sxs_010_px12.ghf.gz
SXS PIX12 EVT	ah100050030sxs_a0px12010_uf.evt.gz	ah100050040sxs_a0px12010_uf.evt.gz
SXS EL GTI	ah100050030sxs_el.gti.gz	ah100050040sxs_el.gti.gz
SXS TEL	ah100050030sxs_tel.gti.gz	ah100050040sxs_tel.gti.gz
SXS PIX GTI	ah100050030sxs_p0px1010.gti.gz	ah100050040sxs_p0px1010.gti.gz
SXS PIX EXP	ah100050030sxs_p0px1010_exp.gti.gz	ah100050040sxs_p0px1010_exp.gti.gz
SXS PIX UF	ah100050030sxs_p0px1010_uf.evt.gz	ah100050040sxs_p0px1010_uf.evt.gz
SXS PIX CL	ah100050030sxs_p0px1010_cl.evt.gz	ah100050040sxs_p0px1010_cl.evt.gz

a) Untar in a directory /full/path/to/data/.

Additional Files

Additional text files for analysis are as follows, and are shown in detail as they are used.

- standard (and other) extraction region files (place in dir /full/path/to/regions)
 - region_SXS_det.reg
 - region_HXI_100050012340.reg
 - region_SXI_100050012340.reg
 - region_HXI1_100050012340_bkg.reg
 - region_HXI2_100050012340_bkg.reg
 - region_SXI_100050012340_bkg.reg
- SXS (for PIXELALL filtering), HXI and SGD lists of gti used for deadtime correction, lists of SXI files to input into addascaspec
 - sxs_ah100050020_gti_PIXELALL.lst
 - ah100050012340hx1_p0camrecpse_cl.gti.lst
 - ah100050012340hx2_p0camrecpse_cl.gti.lst
 - ah100050012340hx1_p0camrec_cl.gti.lst
 - ah100050012340hx2_p0camrec_cl.gti.lst
 - ah10005002340sg1_p0cc1recpse_cl.gti.lst
 - ah10005002340sg1_p0cc2recpse_cl.gti.lst
 - ah10005002340sg1_p0cc3recpse_cl.gti.lst

- addascaspec_normal.in
- addascaspec_mzdye.in

NOTE on source regions files:

- i) 3 arcmin circle (SKY coordinates) for HXI1 and HXI2
- ii) 2.5 arcmin circle (SKY coordinates) for SXI
- iii) Full array (except pixel 12) for SXS (expressed in DET coordinates)

The region centers are determined by estimating the SKY coordinates of the source in the SXI images using the merged event files, and not on the expected source coordinates, although the difference is small.

Note on sequences.

The 100050010, 100050020, 100050030, and 100050040 sequences are similar in content (although the 100050040 exposure is somewhat shorter, and there is no SGD data for 100050010); the 100050020 sequence is used as single-sequence example.

Non-Instrument Specific Processing

ahcalctime

100050020

(1) Recalculate time for HK and unfiltered event files (~120 min)

For illustrative purposes the task is run may be run without time-sorting, which reduces the runtime by a factor of ~10 for files where time becomes out-of-order after re-assignment. In actual applications, set sorttime=yes, as downstream tasks expect event files to be sorted in time.

```
mkdir data/100050020_ahcalctime_output/logs
mv *.log data/100050020_ahcalctime_output/logs
```

ahpipeline

(1) Recalibrate and rescreen data for all instruments using ahpipeline (~40 min)

```
ahpipeline indir=data/100050020 outdir=data/100050020_output
steminputs=ah100050020 stemoutputs=DEFAULT entry_stage=1 exit_stage=2
instrument=ALL verify_input=no create_ehkmkf=yes seed=7 clobber=yes chatter=2
mode=hl

mkdir data/100050020_output/logs
mv *.log data/100050020_output/logs
```

Instrument Specific Reprocessing

100050020

Instrument-specific reprocessing may be applied using `ahpipeline` by changing the `instrument` parameter from `ALL` to `HX, SGD, SXI, or SXS` or by running the individual instrument pipelines as follows.

New files ehk and mkf files, created using the attitude file start and stop times and current, optical axis positions are used as input (not necessary if the reprocessing is for the purpose of recalibrating the data).

Alternatively, mkf and ehk files created by `ahpipeline`, if previously run with `create_ehkmkf=yes`, may be used.

HXI

(1) Recalibrate and rescreen using `hxipipeline` (~9 min)

```
fkeyprint data/100050020/auxil/ah100050020.att.gz+1 TSTART
TSTART = 6.995027610941923E+07 / Start time
fkeyprint data/100050020/auxil/ah100050020.att.gz+1 TSTOP
TSTOP = 7.004526070316976E+07 / Stop time

mkdir data/100050020_repro_hxi
mkdir data/100050020_repro_hxi/tempfhk
cp data/100050020/auxil/*gz data/100050020_repro_hxi/tempfhk
cp data/100050020/hxi/hk/*gz data/100050020_repro_hxi/tempfhk

ahfilter mkfconf=CALDB attfile=data/100050020/auxil/ah100050020.att.gz
orbfile=data/100050020/auxil/ah100050020.orb.gz
outehkfile=data/100050020_repro_hxi/ah100050020.ehk
outmkffile=data/100050020_repro_hxi/ah100050020.mkf reference=NONE
infileroot=data/100050020_repro_hxi/tempfhk/ah100050020
tstart=6.995027610941923E+07 tstop=7.004526070316976E+07
optaxis=1221.08513337811,1209.56130357371,1223.52648309868,1191.20641761044,121
6.11,1217.843,1216.88128249567,1210.32149046794 clobber=yes cleanup=yes
chatter=2 mode=h1

mkdir data/100050020_repro_hxi/logs
mv *.log data/100050020_repro_hxi/logs

hxipipeline indir=data/100050020 outdir=data/100050020_repro_hxi
steminputs=ah100050020 stemoutputs=DEFAULT instrument=HXI entry_stage=1
exit_stage=2 verify_input=no attitude=data/100050020/auxil/ah100050020.att.gz
orbit=data/100050020/auxil/ah100050020.orb.gz
extended_housekeeping=data/100050020_repro_hxi/ah100050020.ehk
makefilter=data/100050020_repro_hxi/ah100050020.mkf
obsgti=data/100050020/auxil/ah100050020_gen.gti.gz seed=7 clobber=yes chatter=2
mode=h1

mv *.log data/100050020_repro_hxi/logs
```

SGD

(1) Recalibrate and rescreen using `sgdpipeline` (~12 min)

```
fkeyprint data/100050020/auxil/ah100050020.att.gz+1 TSTART
TSTART = 6.995027610941923E+07 / Start time
fkeyprint data/100050020/auxil/ah100050020.att.gz+1 TSTOP
```

```

TSTOP = 7.004526070316976E+07 / Stop time

mkdir data/100050020_repro_sgd
mkdir data/100050020_repro_sgd/tempfhk
cp data/100050020/auxil/*gz data/100050020_repro_sgd/tempfhk
cp data/100050020/sgd/hk/*gz data/100050020_repro_sgd/tempfhk

ahfilter mkfconf=CALDB attfile=data/100050020/auxil/ah100050020.att.gz
orbfile=data/100050020/auxil/ah100050020.orb.gz
outehkfile=data/100050020_repro_sgd/ah100050020.ehk
outmkffile=data/100050020_repro_sgd/ah100050020.mkf reference=NONE
infileroot=data/100050020_repro_sgd/tempfhk/ah100050020
tstart=6.995027610941923E+07 tstop=7.004526070316976E+07
optaxis=1221.08513337811,1209.56130357371,1223.52648309868,1191.20641761044,121
6.11,1217.843,1216.88128249567,1210.32149046794 clobber=yes cleanup=yes
chatter=2 mode=h1

mkdir data/100050020_repro_sgd/logs
mv *.log data/100050020_repro_sgd/logs

sgdpipeline indir=data/100050020 outdir=data/100050020_repro_sgd
steminputs=ah100050020 stemoutputs=DEFAULT instrument=SGD entry_stage=1
exit_stage=2 verify_input=no
extended_housekeeping=data/100050020_repro_sgd/ah100050020.ehk
makefilter=data/100050020_repro_sgd/ah100050020.mkf
obsgti=data/100050020/auxil/ah100050020_gen.gti.gz seed=7 clobber=yes chatter=2
mode=h1

mv *.log data/100050020_repro_sgd/logs

```

SXI

(1) Recalibrate and rescreen using sxipipeline (~11 min)

```

fkeyprint data/100050020/auxil/ah100050020.att.gz+1 TSTART
TSTART = 6.995027610941923E+07 / Start time
fkeyprint data/100050020/auxil/ah100050020.att.gz+1 TSTOP
TSTOP = 7.004526070316976E+07 / Stop time

mkdir data/100050020_repro_sxi
mkdir data/100050020_repro_sxi/tempfhk
cp data/100050020/auxil/*gz data/100050020_repro_sxi/tempfhk
cp data/100050020/sgd/hk/*gz data/100050020_repro_sxi/tempfhk

ahfilter mkfconf=CALDB attfile=data/100050020/auxil/ah100050020.att.gz
orbfile=data/100050020/auxil/ah100050020.orb.gz
outehkfile=data/100050020_repro_sxi/ah100050020.ehk
outmkffile=data/100050020_repro_sxi/ah100050020.mkf reference=NONE
infileroot=data/100050020_repro_sxi/tempfhk/ah100050020 tstart=69950336.10941565
tstop=70045200.70317334
optaxis=1221.08513337811,1209.56130357371,1223.52648309868,1191.20641761044,121
6.11,1217.843,1216.88128249567,1210.32149046794 clobber=yes cleanup=yes
chatter=2 mode=h1

mkdir data/100050020_repro_sxi/logs
mv *.log data/100050020_repro_sxi/logs

sxipipeline indir=data/100050020 outdir=data/100050020_repro_sxi
steminputs=ah100050020 stemoutputs=DEFAULT entry_stage=1 exit_stage=2
attitude=data/100050020/auxil/ah100050020.att.gz
orbit=data/100050020/auxil/ah100050020.orb.gz
extended_housekeeping=data/100050020_repro_sxi/ah100050020.ehk
makefilter=data/100050020_repro_sxi/ah100050020.mkf

```

```

obsgti=data/100050020/auxil/ah100050020_gen.gti.gz
housekeeping=data/100050020/sxi/hk/ah100050020sxi_a0.hk.gz seed=7 clobber=yes
chatter=2 mode=hl

mv *.log data/100050020_repro_sxi/logs

```

SXS

(1) Recalibrate/rescreen using sxspipeline (~3 min)

```

fkeyprint data/100050020/auxil/ah100050020.att.gz+1 TSTART
TSTART = 6.995027610941923E+07 / Start time
fkeyprint data/100050020/auxil/ah100050020.att.gz+1 TSTOP
TSTOP = 7.004526070316976E+07 / Stop time

mkdir data/100050020_repro_sxs
mkdir data/100050020_repro_sxs/tempfhk
cp data/100050020/auxil/*gz data/100050020_repro_sxs/tempfhk
cp data/100050020/sxs/hk/*gz data/100050020_repro_sxs/tempfhk

ahfilter mkfconf=CALDB attfile=data/100050020/auxil/ah100050020.att.gz
orbfile=data/100050020/auxil/ah100050020.orb.gz
outehkfile=data/100050020_repro_sxs/ah100050020.ehk
outmkffile=data/100050020_repro_sxs/ah100050020.mkf reference=NONE
infileroot=data/100050020_repro_sxs/tempfhk/ah100050020 tstart=69950336.10941565
tstop=70045200.70317334
optaxis=1221.08513337811,1209.56130357371,1223.52648309868,1191.20641761044,121
6.11,1217.843,1216.88128249567,1210.32149046794 clobber=yes cleanup=yes
chatter=2 mode=hl

mkdir data/100050020_repro_sxs/logs
mv *.log data/100050020_repro_sxs/logs

sxspipeline indir=data/100050020 outdir=data/100050020_repro_sxs
steminputs=ah100050020 stemoutputs=DEFAULT entry_stage=1 exit_stage=2
altitude=data/100050020/auxil/ah100050020.att.gz
orbit=data/100050020/auxil/ah100050020.orb.gz
extended_housekeeping=data/100050020_repro_sxs/ah100050020.ehk
makefilter=data/100050020_repro_sxs/ah100050020.mkf
obsgti=data/100050020/auxil/ah100050020_gen.gti.gz
housekeeping=data/100050020/sxs/hk/ah100050020sxs_a0.hk1.gz
timfile=data/100050020/auxil/ah100050020.tim.gz seed=7 clobber=yes chatter=2
mode=hl

mv *.log data/100050020_repro_sxs/logs

```

(2) Recalibrate/rescreen using sxspipeline, excluding lost event GTI

Setting screenlost=yes results in the screening, for *all* pixels, of lost event intervals for *any* pixel. Unlike in the standard case, the lost event intervals per pixel should not be included in the exposure map used to create the ARF (see below). This option should not be used unless there is little or no pixel-to-pixel variation in the lost GTI intervals. Note that, in this case, the lost event intervals are also excluded by other criteria. As a result the output is the same as for the standard screening. The original ehk and mkf files are used here.

```

sxspipeline indir=data/100050020 outdir=data/100050020_repro2_sxs/sxs
steminputs=ah100050020 stemoutputs=ah100050020 entry_stage=1 exit_stage=2
altitude=data/100050020/auxil/ah100050020.att.gz
orbit=data/100050020/auxil/ah100050020.orb.gz
obsgti=data/100050020/auxil/ah100050020_gen.gti.gz
housekeeping=data/100050020/sxs/hk/ah100050020sxs_a0.hk1.gz
timfile=data/100050020/auxil/ah100050020.tim.gz

```

```

extended_housekeeping=data/100050020/auxil/ah100050020.ehk.gz
makefilter=data/100050020/auxil/ah100050020.mkf.gz screenlost=yes seed=7
clobber=yes chatter=2 mode=h1

mkdir data/100050020_repro2_sxs/logs
mv *log data/100050020_repro2_sxs/logs

```

Extracting Products

This section details tools to run on cleaned event files to get instrument specific data products. These may be applied to the original cleaned event files from the pipeline, or to new cleaned event files created using the steps in the last section. In what follows, the original pipeline cleaned event files are used. The extraction region files described above are assumed to be in the `regions` directory.

100050020

HXI

All newly created output files in this section are placed in the `/full/path/to/data/hxi_products` directory

```

cd /full/path/
mkdir data/products_hxi
cd data/products_hxi

```

(1) Extract source spectra and light curves using xselect

The content of the region file used here, `.../regions/region_HXI_100050012340.reg`, is

```

# Region file format: DS9 version 4.1
fk5
circle(278.3889,-10.5691,180.0000") # font="helvetica 30 normal "

```

HXII

```

xselect
xsel:SUZAKU > read events
.../100050020/hxi/event_cl/ah100050020hx1_p0camrec_cl.evt.gz
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > filter region
.../regions/region_HXI_100050012340.reg
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > extract spectrum
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > save spectrum ah100050020hx1_p0camrec_cl.pi
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > plot spectrum
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > extract curve
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > save curve ah100050020hx1_p0camrec_cl.lc
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > plot curve

```

HXI2

```

xsel:SUZAKU > read events
.../100050020/hxi/event_cl/ah100050020hx2_p0camrec_cl.evt.gz
xsel:HITOMI-HXI2-CAMERA_NORMAL1 > filter region
.../regions/region_HXI_100050012340.reg
xsel:HITOMI-HXI2-CAMERA_NORMAL1 > extract spectrum
xsel:HITOMI-HXI2-CAMERA_NORMAL1 > save spectrum ah100050020hx2_p0camrec_cl.pi
xsel:HITOMI-HXI2-CAMERA_NORMAL1 > plot spectrum
xsel:HITOMI-HXI2-CAMERA_NORMAL1 > extract curve

```

```
xsel: HITOMI-HXI2-CAMERA_NORMAL1 > save curve ah100050020hx2_p0camrec_cl.lc
xsel: HITOMI-HXI2-CAMERA_NORMAL1 > plot curve
```

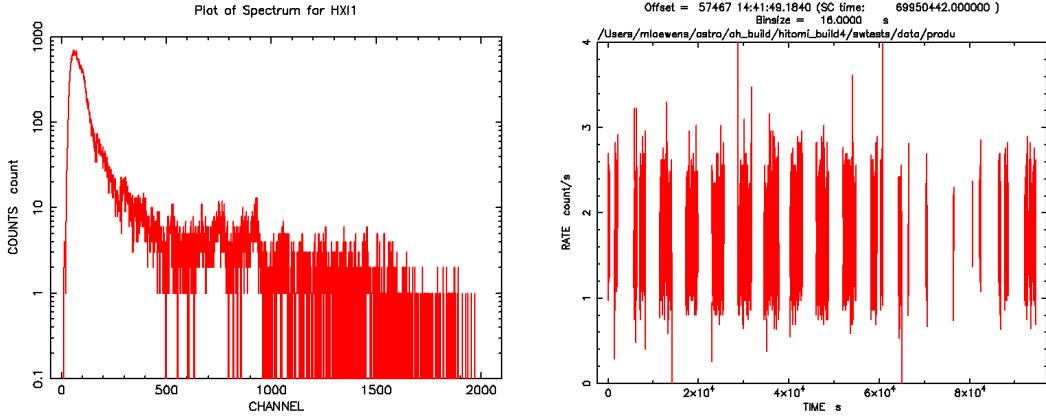


Figure 1: HXI1 source spectrum and lightcurve for sequence 100050020

(2) Run hxisgddtime to correct the spectrum and light curve for dead time

Go back to /full/path/to/data/.. (the directory above the data directory)

```
cd ../../
```

HXI1

```
hxisgddtime
infile=data/100050020/hxi/event_cl/ah100050020hx1_p0camrecpse_cl.evt.gz
inlcfile=data/products_hxi/ah100050020hx1_p0camrec_cl.lc
inspecfile=data/products_hxi/ah100050020hx1_p0camrec_cl.pi
outlcfile=data/products_hxi/ah100050020hx1_p0camrec_dtime.lc
outfile=data/products_hxi/ah100050020hx1_p0camrec_dtime.pi
gtifile=data/100050020/hxi/event_cl/ah100050020hx1_p0camrec_cl.evt.gz chatter=2
clobber=yes

mv hxisgddtime.log data/products_hxi/hxisgddtime_ah100050020hx1.log
```

HXI2

```
hxisgddtime
infile=data/100050020/hxi/event_cl/ah100050020hx2_p0camrecpse_cl.evt.gz
inlcfile=data/products_hxi/ah100050020hx2_p0camrec_cl.lc
inspecfile=data/products_hxi/ah100050020hx2_p0camrec_cl.pi
outlcfile=data/products_hxi/ah100050020hx2_p0camrec_dtime.lc
outfile=data/products_hxi/ah100050020hx2_p0camrec_dtime.pi
gtifile=data/100050020/hxi/event_cl/ah100050020hx2_p0camrec_cl.evt.gz chatter=2
clobber=yes

mv hxisgddtime.log data/products_hxi/hxisgddtime_ah100050020hx2.log
```

(3) Apply barycenter corrections for light curves

```
barycen infile=data/products_hxi/ah100050020hx1_p0camrec_dtime.lc
outfile=data/products_hxi/ah100050020hx1_p0camrec_dtime_add_bary.lc
orbfile=data/100050020/auxil/ah100050020.orb.gz ra=278.38988 dec=-10.56875
orbext=ORBIT chatter=2 clobber=yes

mv barycen.log data/products_hxi/barycen_ah100050020hx1.log
```

```

barycen infile=data/products_hxi/ah100050020hx2_p0camrec_dtime.lc
outfile=data/products_hxi/ah100050020hx2_p0camrec_dtime_add_bary.lc
orbfile=100050020/auxil/ah100050020.orb.gz ra=278.38988 dec=-10.56875
orbext=ORBIT chatter=2 clobber=yes

mv barycen.log data/products_hxi/barycen_ah100050020hx2.log

```

Note that the `ra` and `dec` parameters are set here to the object coordinates as an approximation of the true average pointing direction; this setting can be refined by generating and examining the exposure map (see below).

The barycenter correction may also be applied to event files.

SGD

All newly created output files in this section are placed in the `/full/path/to/data/sgd_products` directory

```
cd /full/path/
```

```
mkdir data/products_sgd
```

```
cd data/products_sgd
```

(1) Extract source spectrum and light curves, summed over all Compton cameras, using xselect

```

xselect
xsel:SUZAKU > read events
..../100050020/sgd/event_cl/ah100050020sg1_p0cc1rec_cl.evt.gz
xsel:HITOMI-SGD1-CC_NORMAL1 > read events
..../100050020/sgd/event_cl/ah100050020sg1_p0cc2rec_cl.evt.gz
xsel:HITOMI-SGD1-CC_NORMAL1 > read events
..../100050020/sgd/event_cl/ah100050020sg1_p0cc3rec_cl.evt.gz
xsel:HITOMI-SGD1-CC_NORMAL1 > extract events
xsel:HITOMI-SGD1-CC_NORMAL1 > save events ah100050020sg1_p0ccALLrec_cl.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > extract spectrum
xsel:HITOMI-SGD1-CC_NORMAL1 > plot spectrum
xsel:HITOMI-SGD1-CC_NORMAL1 > save spectrum ah100050020sg1_p0ccALLrec_cl.pi
xsel:HITOMI-SGD1-CC_NORMAL1 > extract curve
xsel:HITOMI-SGD1-CC_NORMAL1 > plot curve
xsel:HITOMI-SGD1-CC_NORMAL1 > save curve ah100050020sg1_p0ccALLrec_cl_lc

```

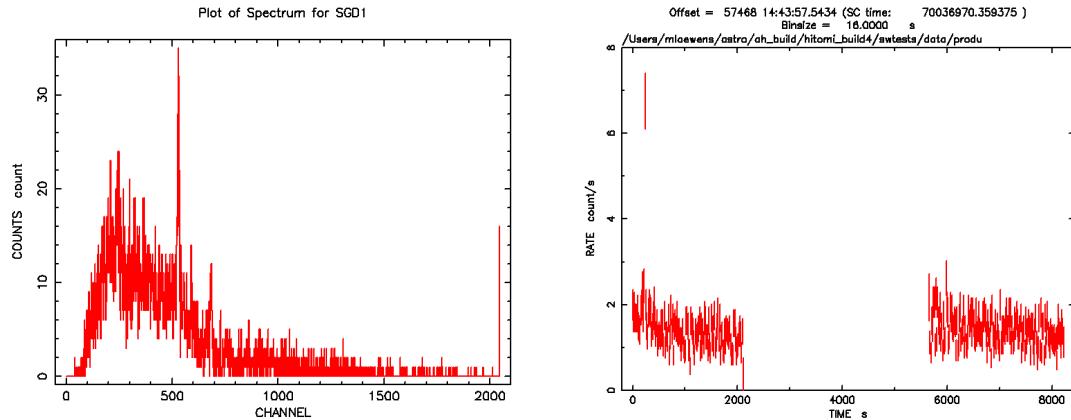


Figure 2: SGD1 source spectrum and lightcurve for sequence 100050020

(2) Run hxisgddtime to correct the spectrum and light curve for dead time

First, extract the spectrum and light curve for each individual camera.

```
xselect
xsel:SUZAKU > read events
..../100050020/sgd/event_cl/ah100050020sg1_p0cc1rec_cl.evt.gz
xsel:HIOMI-SGD1-CC_NORMAL1 > extract spectrum
xsel:HIOMI-SGD1-CC_NORMAL1 > save spectrum ah100050020sg1_p0cc1rec_cl.pi
xsel:HIOMI-SGD1-CC_NORMAL1 > extract curve
xsel:HIOMI-SGD1-CC_NORMAL1 > save curve ah100050020sg1_p0cc1rec_cl.lc
xsel:HIOMI-SGD1-CC_NORMAL1 > clear all
xsel:HIOMI-SGD1-CC_NORMAL1 > read events
..../100050020/sgd/event_cl/ah100050020sg1_p0cc2rec_cl.evt.gz
xsel:HIOMI-SGD1-CC_NORMAL1 > extract spectrum
xsel:HIOMI-SGD1-CC_NORMAL1 > save spectrum ah100050020sg1_p0cc2rec_cl.pi
xsel:HIOMI-SGD1-CC_NORMAL1 > extract curve
xsel:HIOMI-SGD1-CC_NORMAL1 > save curve ah100050020sg1_p0cc2rec_cl.lc
xsel:HIOMI-SGD1-CC_NORMAL1 > clear all
xsel:HIOMI-SGD1-CC_NORMAL1 > read events
..../100050020/sgd/event_cl/ah100050020sg1_p0cc3rec_cl.evt.gz
xsel:HIOMI-SGD1-CC_NORMAL1 > extract spectrum
xsel:HIOMI-SGD1-CC_NORMAL1 > save spectrum ah100050020sg1_p0cc3rec_cl.pi
xsel:HIOMI-SGD1-CC_NORMAL1 > extract
xsel:HIOMI-SGD1-CC_NORMAL1 > save curve ah100050020sg1_p0cc3rec_cl.lc
```

Apply the deadtime correction to each camera

```
hxisgddtime
infile=..../100050020/sgd/event_cl/ah100050020sg1_p0cc1rec_cl.evt.gz
inlcfile=ah100050020sg1_p0cc1rec_cl.lc inspecfile=ah100050020sg1_p0cc1rec_cl.pi
outlcfile=ah100050020sg1_p0cc1rec_dtime.lc
outfile=ah100050020sg1_p0cc1rec_dtime.pi
gtifile=..../100050020/sgd/event_cl/ah100050020sg1_p0cc1rec_cl.evt.gz chatter=2
clobber=yes

mv hxisgddtime.log hxisgddtime_ah100050020sg1cc1.log

hxisgddtime
infile=..../100050020/sgd/event_cl/ah100050020sg1_p0cc2rec_cl.evt.gz
inlcfile=ah100050020sg1_p0cc2rec_cl.lc inspecfile=ah100050020sg1_p0cc2rec_cl.pi
outlcfile=ah100050020sg1_p0cc2rec_dtime.lc
outfile=ah100050020sg1_p0cc2rec_dtime.pi
gtifile=..../100050020/sgd/event_cl/ah100050020sg1_p0cc2rec_cl.evt.gz chatter=2
clobber=yes

mv hxisgddtime.log hxisgddtime_ah100050020sg1cc2.log

hxisgddtime
infile=..../100050020/sgd/event_cl/ah100050020sg1_p0cc3rec_cl.evt.gz
inlcfile=ah100050020sg1_p0cc3rec_cl.lc inspecfile=ah100050020sg1_p0cc3rec_cl.pi
outlcfile=ah100050020sg1_p0cc3rec_dtime.lc
outfile=ah100050020sg1_p0cc3rec_dtime.pi
gtifile=..../100050020/sgd/event_cl/ah100050020sg1_p0cc3rec_cl.evt.gz chatter=2
clobber=yes

mv hxisgddtime.log hxisgddtime_ah100050020sg1cc3.log
```

Add the individual spectra, and add the keywords needed by *sgdarfgen* read from the header of any of the individual spectra (identified using *fkeyprint*), and with the EXPOSURE set to the average of the three individual spectra.

```

mathpha
expr=ah100050020sg1_p0cc1rec_dtime.pi+ah100050020sg1_p0cc2rec_dtime.pi+ah100050
020sg1_p0cc3rec_dtime.pi units=C outfil=ah100050020sg1_p0ccALLrec_dtime.pi
exposure=2962.33 areascal=% backscal=% ncomments=0

fthedit ah100050020sg1_p0ccALLrec_dtime.pi+1 RA_NOM a 278.385976096973
fthedit ah100050020sg1_p0ccALLrec_dtime.pi+1 DEC_NOM a -10.5700756067587
fthedit ah100050020sg1_p0ccALLrec_dtime.pi+1 PA_NOM a 88.4915688237262
fthedit ah100050020sg1_p0ccALLrec_dtime.pi+1 DATE-OBS a 2016-03-
21T14:42:41.359375

```

Steps 1 and 2 should be repeated for sequences ah100050030, and ah100050040.

SXI

All newly created output files in this section are placed in the /full/path/to/data/sxi_products directory

```

cd /full/path/
mkdir data/products_sxi
cd data/products_sxi

```

There are two cleaned SXI event files for each of the G21.5-0.9 sequences, e.g. for sequence 100050020:

```

../100050020/sxi/event_cl/ah100050020sxi_p0100004b0_cl.evt.gz
../100050020/sxi/event_cl/ah100050020sxi_p0100004b1_cl.evt.gz

```

The files ending in “1”, i.e. “p0100004b1”, refer to “Minus-Z Day Earth” (MZDYE) data conducted with area discrimination on and different event thresholds. These must be independently analyzed from the files ending in “0” or “Normal” data files. To reduce the background in the extracted image, the “Normal” event list is filtered by energy to 0.5-8 keV. For the “MZDYE” event list, this would remove all the counts away from the source, so the full energy range is used for the image.

The content of the region file used here, .../regions/region_SXI_100050012340.reg, is

```

# Region file format: DS9 version 4.1
fk5
circle(278.3889,-10.5691,150") # color=white font="helvetica 30 normal "
#

```

(1) Extract images, source spectra, and light curves using xselect

Normal Mode

```

xselect
xsel:SUZAKU > read events
./100050020/sxi/event_cl/ah100050020sxi_p0100004b0_cl.evt.gz
xsel:HITOMI-SXI-WINDOW1 > filter pha_cutoff 83 1333
xsel:HITOMI-SXI-WINDOW1 > set xybin 4
xsel:HITOMI-SXI-WINDOW1 > extract image
xsel:HITOMI-SXI-WINDOW1 > save image ah100050020sxi_p0100004b0_cl.img
xsel:HITOMI-SXI-WINDOW1 > plot image
xsel:HITOMI-SXI-WINDOW1 > clear pha_cutoff
xsel:HITOMI-SXI-WINDOW1 > filter region
.../regions/region_SXI_100050012340.reg
xsel:HITOMI-SXI-WINDOW1 > extract spectrum
xsel:HITOMI-SXI-WINDOW1 > save spectrum ah100050020sxi_p0100004b0_cl.pi
xsel:HITOMI-SXI-WINDOW1 > plot spectrum
xsel:HITOMI-SXI-WINDOW1 > extract curve exposure=0.0

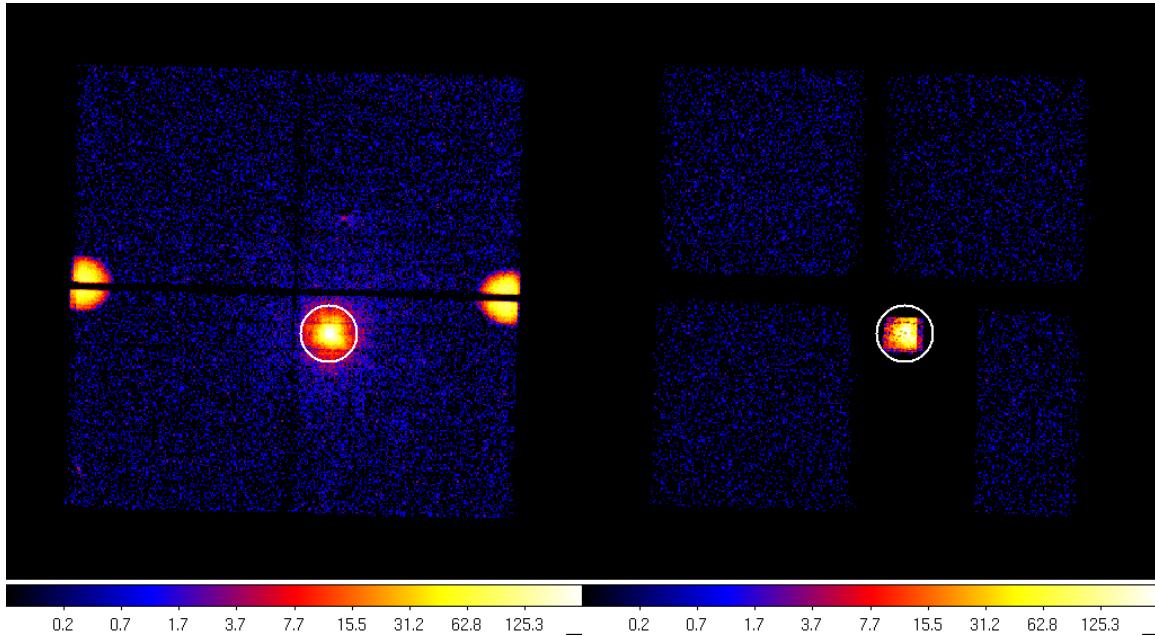
```

```
xsel: HITOMI-SXI-WINDOW1 > save curve ah100050020sxi_p0100004b0_cl.lc  
xsel: HITOMI-SXI-WINDOW1 > plot curve
```

MZDYE

```
xselect  
xsel:SUZAKU > read events  
..../100050020/sxi/event_cl/ah100050020sxi_p0100004b1_cl.evt.gz  
xsel:HITOMI-SXI-WINDOW1 > set xybin 4  
xsel:HITOMI-SXI-WINDOW1 > extract image  
xsel:HITOMI-SXI-WINDOW1 > save image ah100050020sxi_p0100004b1_cl.img  
xsel:HITOMI-SXI-WINDOW1 > filter region  
..../regions/region_SXI_100050012340.reg  
xsel:HITOMI-SXI-WINDOW1 > extract spectrum  
xsel:HITOMI-SXI-WINDOW1 > save spectrum ah100050020sxi_p0100004b1_cl.pi  
xsel:HITOMI-SXI-WINDOW1 > plot spectrum  
xsel:HITOMI-SXI-WINDOW1 > extract curve exposure=0.0  
xsel:HITOMI-SXI-WINDOW1 > save curve ah100050020sxi_p0100004b1_cl.lc  
xsel:HITOMI-SXI-WINDOW1 > plot curve
```

Step 1 is repeated for sequences ah100050010, ah100050030, and ah100050040.



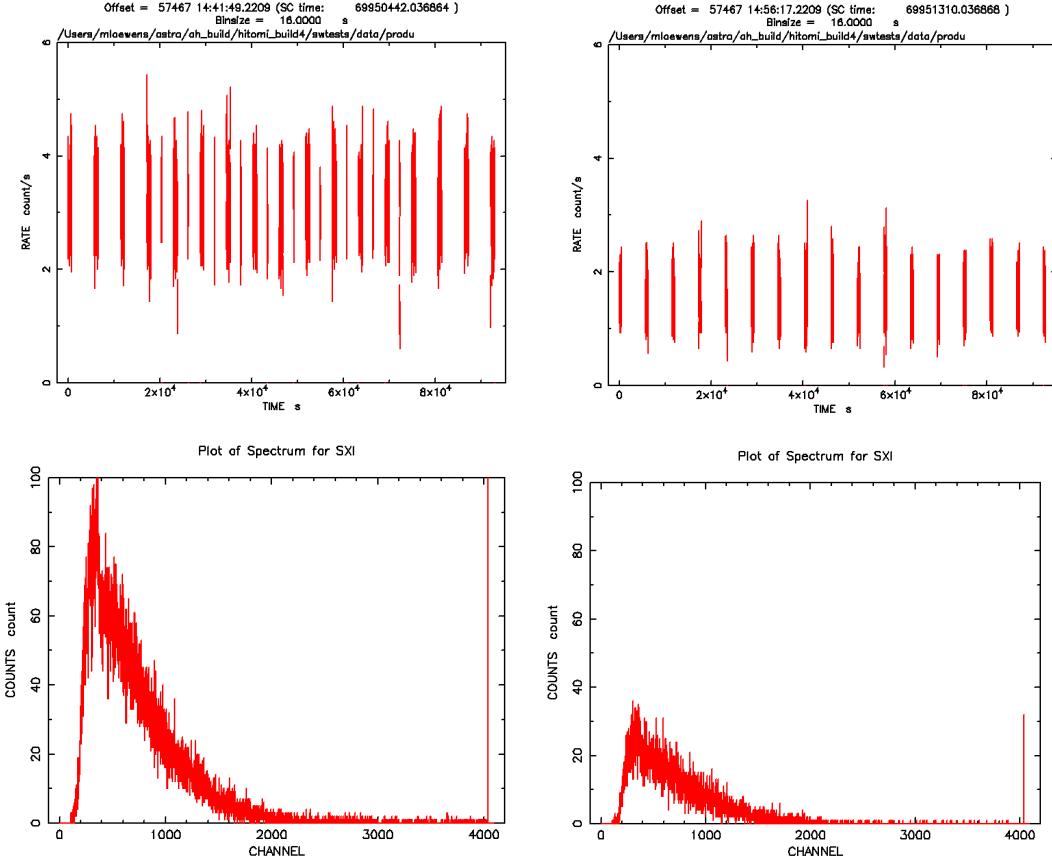


Figure 3: SXI images (with extraction region), lightcurves, and source spectra for sequence 100050020 – normal (left) and Minus Z Day Earth mode (right).

(2) Extract background spectra, and light curves using xselect

Background is extracted from the full field of view of only the ‘Normal’ data, excluding the calibration source regions, the readout streaks from the calibration sources, some point sources, and a 9 arcmin circle centered on the source.

The content of the region file used here, `.../regions/region_SXI_100050012340_bkg.reg`, is

```
# Region file format: DS9 version 4.1
global color=green dashlist=8 3 width=1 font="helvetica 10 normal roman"
select=1 highlite=1 dash=0 fixed=0 edit=1 move=1 delete=1 include=1 source=1
fk5
box(278.44244,-10.510651,2167.6579",1769.1332",88.49) # color=white width=2
-circle(278.38824,-10.570683,540") # color=white width=2
-circle(278.36627,-10.407636,120") # color=white width=2
-circle(278.25239,-10.490114,120") # color=white width=2
-circle(278.31736,-10.396696,120") # color=white width=2
-circle(278.21838,-10.485218,120") # color=white width=2
-circle(278.25057,-10.608779,120") # color=white width=2
-circle(278.50636,-10.46556,120") # color=white width=2
-circle(278.54299,-10.358399,120") # color=white width=2
-circle(278.60766,-10.643718,120") # color=white width=2
-circle(278.40962,-10.389049,120") # color=white width=2
```

Alternatively, a smaller region on the same chip may be selected.

Normal Mode

```

xselect
xsel:SUZAKU > read events
..../100050020/sxi/event_cl/ah100050020sxi_p0100004b0_cl.evt.gz
xsel:HITOMI-SXI-WINDOW1 > filter region
..../regions/region_SXI_100050012340_bkg.reg
xsel:HITOMI-SXI-WINDOW1 > extract spectrum
xsel:HITOMI-SXI-WINDOW1 > save spectrum ah100050020sxi_p0100004b0_cl_bkg.pi
xsel:HITOMI-SXI-WINDOW1 > plot spectrum
xsel:HITOMI-SXI-WINDOW1 > extract curve exposure=0.0
xsel:HITOMI-SXI-WINDOW1 > save curve ah100050020sxi_p0100004b0_cl_bkg.lc
xsel:HITOMI-SXI-WINDOW1 > plot curve

```

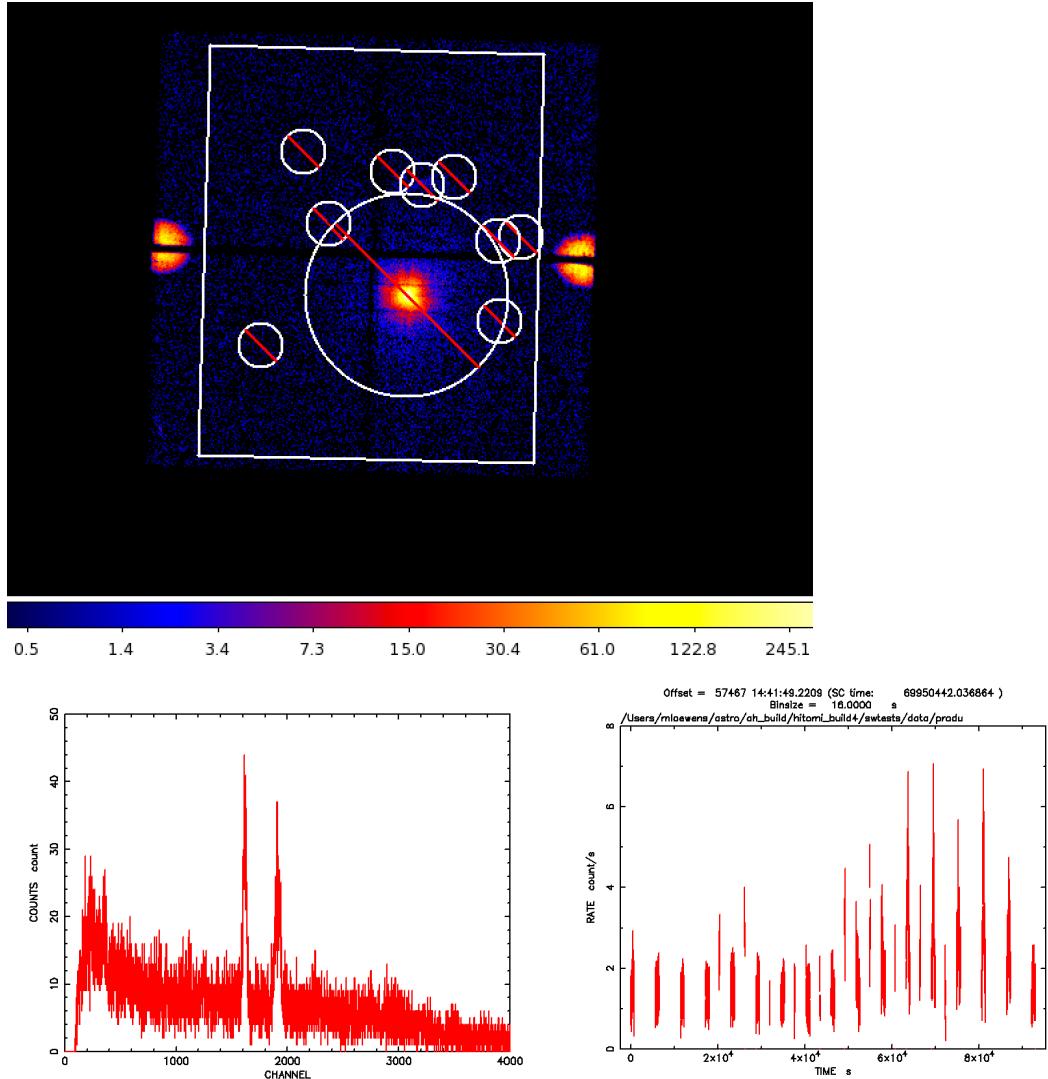


Figure 4: SXI image with cal-source region excluded and background extraction region (top), and combined background spectrum (bottom left) and lightcurve (bottom right) for sequence 100050020.

Step 2 is repeated for sequences ah100050010, ah100050030, and ah100050040.

SXS

All newly created output files in this section are placed in the /full/path/to/data/sxs_products directory

```

cd /full/path/
mkdir data/products_sxs
cd data/products_sxs

```

(1) Additional screening

Create a “cleaned-2” SXS event file

```
ah100050020sxs_p0px1010_c12.evt
```

by applying a RISETIME cut to Hp, Mp, Ms, and Lp (but not Ls) events.

```

ftselect
infile='..../100050020/sxs/event_cl/ah100050020sxs_p0px1010_c1.evt.gz[events]'
outfile=ah100050020sxs_p0px1010_c12.evt expression="(PI>=400)&&((RISE_TIME>=40
&& RISE_TIME<=60 && ITYPE<4) || (ITYPE==4))"

```

Note that the current pipeline screening already excludes events with PI<600.

(2) Alternative SXS event filtering

An alternative label in the CALDB mkf configuration (PIXELALL) includes an ADR recycle stability criterion defined by two SXS housekeeping parameters that measure the standard deviation in the temperature measure by separate thermometers (ADRC_CT_CTL_FLUC and ADRC_CT_MON_FLUC), that is not applied in the default pipeline SXS event screening. The procedure to create the alternative cleaned file:

```
ah100050020sxs_p0px1010_c12b.evt
```

is as follows:

a) Create the mkf GTI corresponding to the PIXELALL label

```

ahgtigen infile=..../100050020/auxil/ah100050020.mkf.gz
outfile=ah100050020_sxs_mkf_PIXELALL.gti gtiexpr=None mergegti=AND
selectfile=CALDB label=PIXELALL instrume=SXS pref=0.0 postfr=1.0

```

b) Create the ehk GTI

```

ahgtigen infile=..../100050020/auxil/ah100050020.ehk.gz
outfile=ah100050020_sxs_ek_PIXELALL.gti gtiexpr=None mergegti=AND
selectfile=CALDB label=PIXELALL instrume=SXS pref=0.0 postfr=1.0

```

c) Create (or place in the working directory) the text file sxs_ah100050020_gti_PIXELALL.lst, which lists all of the SXS gti file extensions to use in screening. The list includes the two made in the previous two steps, as well as the GTI in the original unfiltered event file, the non-saturated telemetry GTI, the pointing GTI, the good attitude GTI, and the ADR cycle intervals when the gain is stable:

```

..../100050020/sxs/event_uf/ah100050020sxs_p0px1010_uf.evt.gz+2
..../100050020/sxs/event_uf/ah100050020sxs_tel.gti.gz+1
..../100050020/auxil/ah100050020_gen.gti.gz+2
..../100050020/auxil/ah100050020_gen.gti.gz+5
ah100050020_sxs_ek_PIXELALL.gti+1
ah100050020_sxs_mkf_PIXELALL.gti+1
..../100050020/sxs/event_uf/ahsxs_adr.gti.gz+2

```

One may add `../100050020/ah100050020sxs_el.gti.gz+3` to this list to exclude the GTI when there are no LOST events in any pixel.

d) Create a GTI file that merges all the GTI in the list in step (c):

```
ahgtigen infile=NONE outfile=ah100050020sxs_PIXELALL.gti
gtifile=@sxs_ah100050020_gti_PIXELALL.lst gtiexpr=NONE mergegti=AND
```

e) Screen the data using the merged GTI file created in step (d), the extra RISETIME screening described above, and the latest screening criteria:

```
ahscreen infile=../100050020/sxs/event_uf/ah100050020sxs_p0px1010_uf.evt.gz
outfile=ah100050020sxs_p0px1010_cl2b.evt gtifile=ah100050020sxs_PIXELALL.gti
expr="ITYPE<5&&(SLOPE_DIFFER==b0||PI>25000)&&QUICK_DOUBLE==b0&&STATUS[3]==b0&&STATUS[4]==b0&&STATUS[6]==b0&&STATUS[2]==b0&&PI>600&&((RISE_TIME>=40&&RISE_TIME<=60&&ITYPE<4)|||RISE_TIME<127&&ITYPE==4))&&PIXEL!=12&&TICK_SHIFT>-8&&TICK_SHIFT<7" mergegti=AND selectfile=CALDB label=None cpkeyword=all
clobber=yes
```

f) Adjust the PI TLMIN and TLMAX keywords (the unfiltered event file included baseline, ITYPE=5, events with PI that may be <0).

```
fthedit ah100050020sxs_p0px1010_cl2b.evt TLMIN45 a 0
fthedit ah100050020sxs_p0px1010_cl2b.evt TLMAX45 a 32767
```

For this dataset, the decrease in the number of events in the cleaned event files is $\sim 10\%$; however, the count rate is virtually unchanged (i.e., the exposure time is also $\sim 10\%$ lower). In what follows we use event files extracted using the pipeline screening (i.e., applying the PIXELALL2 label).

(3) Extract source spectra and light curves using sxsregext or xselect

Use sxsregext to extract the spectrum `ah100050020sxs_region_SXS_det.pha` from the above cleaned-2 event file events `ah100050020sxs_p0px1010_cl2.evt` for Hp events. Here we use the corresponding SXI sky region (which includes all the SXS pixels except pixel 12) as input. The 35-pixel detector region (`ah100050020sxs_region_SXS_det.reg`) and SXS exposure map (`ah100050020sxs_region_SXS_det.expo`) are also created.

```
sxsregext infile=ah100050020sxs_p0px1010_cl2.evt regmode=SKY
region=../../regions/region_SXI_100050012340.reg resolist=0
outroot=ah100050020sxs_region_SXS_det outexp=ah100050020sxs.expo
ehkfile=../100050020/auxil/ah100050020.ehk.gz delta=0.25 numphi=4 clobber=yes
```

The region file `ah100050020sxs_region_SXS_det.reg`

```
physical
+box(4,1,5,1.00000000)
+box(3.5,2,6,1.00000000)
+box(3.5,3,6,1.00000000)
+box(3.5,4,6,1.00000000)
+box(3.5,5,6,1.00000000)
+box(3.5,6,6,1.00000000)
```

includes all non-calibration pixels, as does the generic region file `region_SXS_det.reg`.

In addition to the spectrum, a DET coordinate image `ah100050020sxs_region_sxs_det.img` and lightcurve `ah100050020sxs_region_sxs_det.lc` are created, as displayed below using `ds9` and `lcview`.

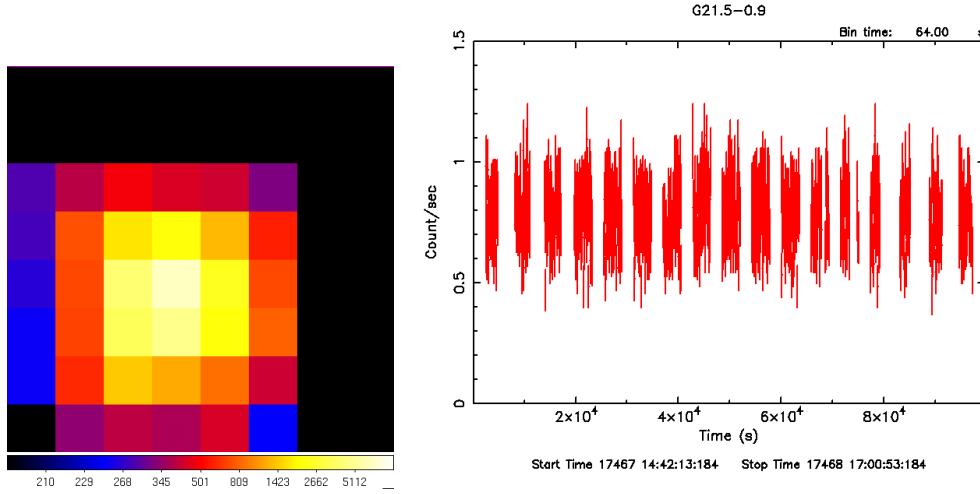


Figure 5: SXS source DET coordinate image and lightcurve for sequence 100050020.

Note that, by default, HP (ITYPE 0) and MP (ITYPE 1) events are included in the spectrum (this may be controlled via the hidden `sxsregext resolist` parameter). Also, note that the `BACKSCAL` keyword is set to `5.468750E-01` which is the ratio of the number of pixels used in the extraction (35) to the total detector address space in pixels (64). This is not a problem provided that any spectra to be combined, subtracted etc. are created in the same manner. The following alternative using `xselect` creates a spectrum with `BACKSCAL=1`:

```
xsel:SUZAKU > read events ah100050020sxs_p0px1010_c12.evt
xsel:HITOMI-SXS-PX_NORMAL > filter column "PIXEL=0:11,13:35"
xsel:HITOMI-SXS-PX_NORMAL > filter GRADE "0:0"
xsel:HITOMI-SXS-PX_NORMAL > extract spectrum
xsel:HITOMI-SXS-PX_NORMAL > save spectrum ah100050020sxs_p0px1010_c12_HP.pi
```

Note that Pixel 12 events may already be excluded from the cleaned event files depending on the label used in filtering; in those cases the second step above may be skipped.

100050010, 100050020, 100050030, 100050040 COMBINED

HXI

All newly created output files in this section are placed in the `/full/path/to/data/hxi_products` directory

```
cd /full/path/
cd data/products_hxi
```

(1) Extract source and background spectra and light curves using xselect

In the absence of an accurate model for the HXI non-X-ray background (NXB), an off-source spectrum may be extracted – although this will necessarily include some of the source emission and is expected to result in an underestimate of the flux. Event files are merged in `xselect` prior to extraction of the source and background spectra and lightcurves.

The content of the background region file used here,
.../regions/region_HXI1_100050012340_bkg.reg, is

```
# Region file format: DS9 version 4.1
fk5
box(278.38669,-10.566035,490",490",-22.5)
-circle(278.3889,-10.5691,180.0000) # font="helvetica 30 normal "
```

HXI1

```
xselect
xsel:SUZAKU > read events
../100050010/hxi/event_cl/ah100050010hx1_p0camrec_cl.evt.gz
xsel:HIKOMI-HXI1-CAMERA_NORMAL1 > read events
../100050020/hxi/event_cl/ah100050020hx1_p0camrec_cl.evt.gz
xsel:HIKOMI-HXI1-CAMERA_NORMAL1 > read events
../100050030/hxi/event_cl/ah100050030hx1_p0camrec_cl.evt.gz
xsel:HIKOMI-HXI1-CAMERA_NORMAL1 > read events
../100050040/hxi/event_cl/ah100050040hx1_p0camrec_cl.evt.gz
xsel:HIKOMI-HXI1-CAMERA_NORMAL1 > extract image
xsel:HIKOMI-HXI1-CAMERA_NORMAL1 > save image ah1000500ALL0hx1_p0camrec_cl.img
xsel:HIKOMI-HXI1-CAMERA_NORMAL1 > plot image
xsel:HIKOMI-HXI1-CAMERA_NORMAL1 > filter region
.../regions/region_HXI1_100050012340.reg
xsel:HIKOMI-HXI1-CAMERA_NORMAL1 > extract spectrum
xsel:HIKOMI-HXI1-CAMERA_NORMAL1 > save spectrum ah1000500ALL0hx1_p0camrec_cl.pi
xsel:HIKOMI-HXI1-CAMERA_NORMAL1 > plot spectrum
xsel:HIKOMI-HXI1-CAMERA_NORMAL1 > extract curve
xsel:HIKOMI-HXI1-CAMERA_NORMAL1 > save curve ah1000500ALL0hx1_p0camrec_cl.lc
xsel:HIKOMI-HXI1-CAMERA_NORMAL1 > plot curve
xsel:HIKOMI-HXI1-CAMERA_NORMAL1 > clear region
xsel:HIKOMI-HIX1-CAMERA_NORMAL1 > filter region
.../regions/region_HXI1_100050012340_bkg.reg
xsel:HIKOMI-HIX1-CAMERA_NORMAL1 > extract spectrum
xsel:HIKOMI-HIX1-CAMERA_NORMAL1 > save spectrum
ah1000500ALL0hx1_p0camrec_cl_bkg.pi
xsel:HIKOMI-HIX1-CAMERA_NORMAL1 > plot spectrum
xsel:HIKOMI-HIX1-CAMERA_NORMAL1 > extract curve
xsel:HIKOMI-HIX1-CAMERA_NORMAL1 > save curve
ah1000500ALL0hx1_p0camrec_cl_bkg.lc
xsel:HIKOMI-HIX1-CAMERA_NORMAL1 > plot curve
```

HXI2

The content of the background region file used here,
.../regions/region_HXI2_100050012340_bkg.reg, is

```
# Region file format: DS9 version 4.1
fk5
box(278.38269,-10.565051,490",490",22.5)
-circle(278.3889,-10.5691,180") # font="helvetica 30 normal "

xselect
xsel:SUZAKU > read events
../100050010/hxi/event_cl/ah100050010hx2_p0camrec_cl.evt.gz
xsel:HIKOMI-HXI2-CAMERA_NORMAL1 > read events
../100050020/hxi/event_cl/ah100050020hx2_p0camrec_cl.evt.gz
xsel:HIKOMI-HXI2-CAMERA_NORMAL1 > read events
../100050030/hxi/event_cl/ah100050030hx2_p0camrec_cl.evt.gz
xsel:HIKOMI-HXI2-CAMERA_NORMAL1 > read events
../100050040/hxi/event_cl/ah100050040hx2_p0camrec_cl.evt.gz
```

```

xsel: HITOMI-HXI2-CAMERA_NORMAL1 > extract image
xsel: HITOMI-HXI2-CAMERA_NORMAL1 > save image ah1000500ALL0hx1_p0camrec_cl.img
xsel: HITOMI-HXI2-CAMERA_NORMAL1 > plot image
xsel: HITOMI-HXI2-CAMERA_NORMAL1 > filter region
../../regions/region_HXI_100050012340.reg
xsel: HITOMI-HXI2-CAMERA_NORMAL1 > extract spectrum
xsel: HITOMI-HXI2-CAMERA_NORMAL1 > save spectrum ah1000500ALL0hx2_p0camrec_cl.pi
xsel: HITOMI-HXI2-CAMERA_NORMAL1 > plot spectrum
xsel: HITOMI-HXI2-CAMERA_NORMAL1 > extract curve
xsel: HITOMI-HXI2-CAMERA_NORMAL1 > save curve ah1000500ALL0hx2_p0camrec_cl.lc
xsel: HITOMI-HXI2-CAMERA_NORMAL1 > plot curve
xsel: HITOMI-HXI2-CAMERA_NORMAL1 > clear region
xsel: HITOMI-HIX2-CAMERA_NORMAL1 > filter region
../../regions/region_HXI2_100050012340_bkg.reg
xsel: HITOMI-HIX2-CAMERA_NORMAL1 > extract spectrum
xsel: HITOMI-HIX2-CAMERA_NORMAL1 > save spectrum
ah1000500ALL0hx2_p0camrec_cl_bkg.pi
xsel: HITOMI-HIX2-CAMERA_NORMAL1 > plot spectrum
xsel: HITOMI-HIX2-CAMERA_NORMAL1 > extract curve
xsel: HITOMI-HIX2-CAMERA_NORMAL1 > save curve
ah1000500ALL0hx2_p0camrec_cl_bkg.lc
xsel: HITOMI-HIX2-CAMERA_NORMAL1 > plot curve

```

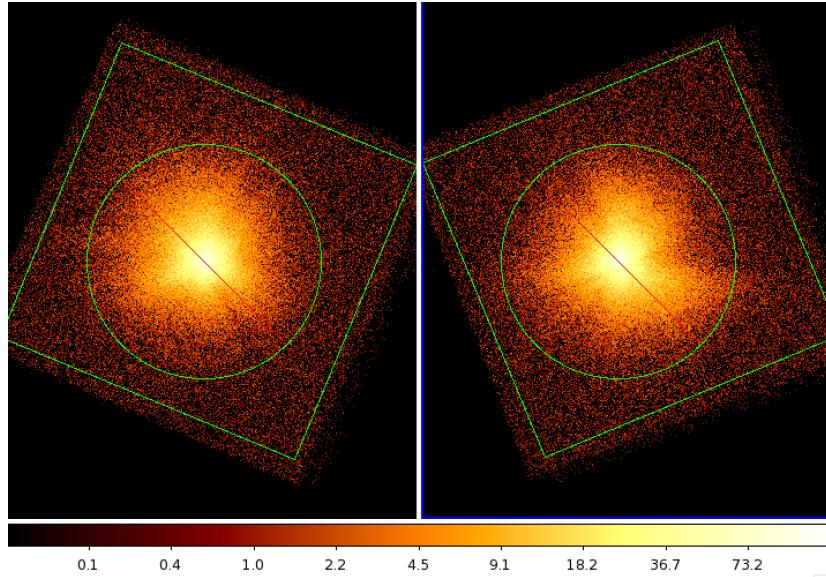


Figure 6: HXI1 (left) and HXI2 (right) background regions.

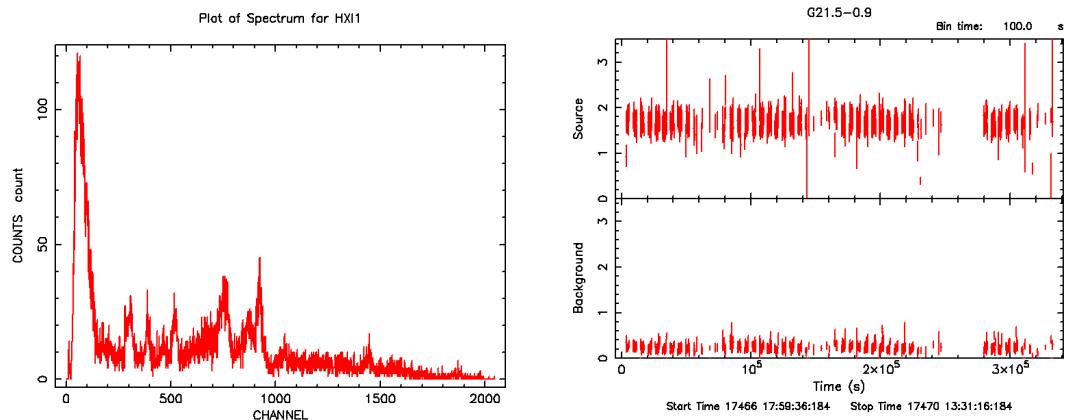


Figure 7: Combined HXI1 background spectrum, and source and background lightcurves, for sequences ah100050010, ah100050020, ah100050030, and ah100050040.

(2) Construct the dead-time corrected source and background spectra using xselect, hxisgddtime, and ahgtigen

HXI1

(a) Merge the pseudo-event files, including their GTI extensions:

```
ftmerge
'.../100050010/hxi/event_cl/ah100050010hx1_p0camrecpse_cl.evt.gz,.../100050020/hxi/event_cl/ah100050020hx1_p0camrecpse_cl.evt.gz,.../100050030/hxi/event_cl/ah100050030hx1_p0camrecpse_cl.evt.gz,.../100050040/hxi/event_cl/ah100050040hx1_p0camrecpse_cl.evt'
ahgtigen infile=NONE outfile=ah1000500ALL0hx1_p0camrecpse_cl.gti
gtifile=@ah100050012340hx1_p0camrecpse_cl.gti.lst gtiexpr=None mergegti=OR
```

where ah100050012340hx1_p0camrecpse_cl.gti.lst is a text file listing all pseudo event file GTI extensions:

```
.../100050010/hxi/event_cl/ah100050010hx1_p0camrecpse_cl.evt.gz+2
.../100050020/hxi/event_cl/ah100050020hx1_p0camrecpse_cl.evt.gz+2
.../100050030/hxi/event_cl/ah100050030hx1_p0camrecpse_cl.evt.gz+2
.../100050040/hxi/event_cl/ah100050040hx1_p0camrecpse_cl.evt.gz+2

ftdelhdu 'ah1000500ALL0hx1_p0camrecpse_cl.evt[GTI]' none confirm=YES

ftappend 'ah1000500ALL0hx1_p0camrecpse_cl.gti[GTI]'
ah1000500ALL0hx1_p0camrecpse_cl.evt
```

(b) Merge the event file GTI extensions:

```
ahgtigen infile=NONE outfile=ah1000500ALL0hx1_p0camrec_cl.gti
gtifile=@ah100050012340hx1_p0camrec_cl.gti.lst gtiexpr=None mergegti=OR
```

where ah100050012340hx1_p0camrec_cl.gti.lst is a text file listing all GTI extensions:

```
.../100050010/hxi/event_cl/ah100050010hx1_p0camrec_cl.evt.gz+2
.../100050020/hxi/event_cl/ah100050020hx1_p0camrec_cl.evt.gz+2
.../100050030/hxi/event_cl/ah100050030hx1_p0camrec_cl.evt.gz+2
.../100050040/hxi/event_cl/ah100050040hx1_p0camrec_cl.evt.gz+2

fthedit ah1000500ALL0hx1_p0camrec_cl.gti+1 INSTRUME a HXI1
fthedit ah1000500ALL0hx1_p0camrec_cl.gti+1 DETNAM a CAMERA
```

(c) Apply the deadtime correction to the merged source and background spectra and lightcurves, using the merged pseudo-event and event GTI files:

```
hxisgddtime infile=ah1000500ALL0hx1_p0camrecpse_cl.evt
inlcfile=ah1000500ALL0hx1_p0camrec_cl.lc
inspecfile=ah1000500ALL0hx1_p0camrec_cl.pi
outlcfile=ah1000500ALL0hx1_p0camrec_dtime.lc
outfile=ah1000500ALL0hx1_p0camrec_dtime.pi
gtifile=ah1000500ALL0hx1_p0camrec_cl.gti

mv hxisgddtime.log hxisgddtime_ah1000500ALL0hx1.log

hxisgddtime infile=ah1000500ALL0hx1_p0camrecpse_cl.evt
inlcfile=ah1000500ALL0hx1_p0camrec_cl_bkg.lc
inspecfile=ah1000500ALL0hx1_p0camrec_cl_bkg.pi
```

```

outlcfile=ah1000500ALL0hx1_p0camrec_dtime_bkg.lc
outfile=ah1000500ALL0hx1_p0camrec_dtime_bkg.pi
gtifile=ah1000500ALL0hx1_p0camrec_cl.gti

mv hxisgddtime.log hxisgddtime_ah1000500ALL0hx1_bkg.log

```

HXI2

(a) Merge the pseudo-event files, including their GTI extensions:

```

ftmerge
'../100050010/hxi/event_cl/ah100050010hx2_p0camrecpse_cl.evt.gz,../100050020/hxi/
event_cl/ah100050020hx2_p0camrecpse_cl.evt.gz,../100050030/hxi/event_cl/ah100050030hx2_
p0camrecpse_cl.evt.gz,../100050040/hxi/event_cl/ah100050040hx2_p0camrecpse_cl.evt'
ah1000500ALL0hx2_p0camrecpse_cl.evt

ahgtigen infile=NONE outfile=ah1000500ALL0hx2_p0camrecpse_cl.gti
gtifile=@ah100050012340hx2_p0camrecpse_cl.gti.lst gtiexpr=NONE mergegti=OR

```

where ah100050012340hx2_p0camrecpse_cl.gti.lst is a text file listing all GTI extensions:

```

../100050010/hxi/event_cl/ah100050010hx2_p0camrecpse_cl.evt.gz+2
../100050020/hxi/event_cl/ah100050020hx2_p0camrecpse_cl.evt.gz+2
../100050030/hxi/event_cl/ah100050030hx2_p0camrecpse_cl.evt.gz+2
../100050040/hxi/event_cl/ah100050040hx2_p0camrecpse_cl.evt.gz+2

ftdelhdu 'ah1000500ALL0hx2_p0camrecpse_cl.evt[GTI]' none confirm=YES

ftappend 'ah1000500ALL0hx2_p0camrecpse_cl.gti[GTI]'
ah1000500ALL0hx2_p0camrecpse_cl.evt

```

(b) Merge the event file GTI extensions:

```

ahgtigen infile=NONE outfile=ah1000500ALL0hx2_p0camrec_cl.gti
gtifile=@ah100050012340hx2_p0camrec_cl.gti.lst gtiexpr=NONE mergegti=OR

```

where ah100050012340hx2_p0camrec_cl.gti.lst is a text file listing all GTI extensions:

```

../100050010/hxi/event_cl/ah100050010hx2_p0camrec_cl.evt.gz+2
../100050020/hxi/event_cl/ah100050020hx2_p0camrec_cl.evt.gz+2
../100050030/hxi/event_cl/ah100050030hx2_p0camrec_cl.evt.gz+2
../100050040/hxi/event_cl/ah100050040hx2_p0camrec_cl.evt.gz+2

fthedit ah1000500ALL0hx2_p0camrec_cl.gti+1 INSTRUME a HXI2
fthedit ah1000500ALL0hx2_p0camrec_cl.gti+1 DETNAM a CAMERA

```

(c) Apply the deadtime correction to the merged source and background spectra and lightcurves, using the merged pseudo-event and event GTI files:

```

hxisgddtime infile=ah1000500ALL0hx2_p0camrecpse_cl.evt
inlcfile=ah1000500ALL0hx2_p0camrec_cl.lc
inspecfile=ah1000500ALL0hx2_p0camrec_cl.pi
outlcfile=ah1000500ALL0hx2_p0camrec_dtime.lc
outfile=ah1000500ALL0hx2_p0camrec_dtime.pi
gtifile=ah1000500ALL0hx2_p0camrec_cl.gti

mv hxisgddtime.log hxisgddtime_ah1000500ALL0hx2.log

hxisgddtime infile=ah1000500ALL0hx2_p0camrecpse_cl.evt
inlcfile=ah1000500ALL0hx2_p0camrec_cl_bkg.lc
inspecfile=ah1000500ALL0hx2_p0camrec_cl_bkg.pi
outlcfile=ah1000500ALL0hx2_p0camrec_dtime_bkg.lc

```

```

outfile=ah1000500ALL0hx2_p0camrec_dtime_bkg.pi
gtifile=ah1000500ALL0hx2_p0camrec_cl.gti

mv hxisgddtime.log hxisgddtime_ah1000500ALL0hx2_bkg.log

```

SGD

All newly created output files in this section are placed in the /full/path/to/data/sgd_products directory

```

cd /full/path/
cd data/products_sgd

```

(1) Extract source spectrum and light curves using xselect

```

xselect
xsel:SUZAKU > read events
..../100050020/sgd/event_cl/ah100050020sg1_p0cc1rec_cl.evt.gz
xsel:HITOMI-SGD1-CC_NORMAL1 > read events
..../100050020/sgd/event_cl/ah100050020sg1_p0cc2rec_cl.evt.gz
xsel:HITOMI-SGD1-CC_NORMAL1 > read events
..../100050020/sgd/event_cl/ah100050020sg1_p0cc3rec_cl.evt.gz
xsel:SUZAKU > read events
..../100050030/sgd/event_cl/ah100050030sg1_p0cc1rec_cl.evt.gz
xsel:HITOMI-SGD1-CC_NORMAL1 > read events
..../100050030/sgd/event_cl/ah100050030sg1_p0cc2rec_cl.evt.gz
xsel:HITOMI-SGD1-CC_NORMAL1 > read events
..../100050030/sgd/event_cl/ah100050030sg1_p0cc3rec_cl.evt.gz
xsel:SUZAKU > read events
..../100050040/sgd/event_cl/ah100050040sg1_p0cc1rec_cl.evt.gz
xsel:HITOMI-SGD1-CC_NORMAL1 > read events
..../100050040/sgd/event_cl/ah100050040sg1_p0cc2rec_cl.evt.gz
xsel:HITOMI-SGD1-CC_NORMAL1 > read events
..../100050040/sgd/event_cl/ah100050040sg1_p0cc3rec_cl.evt.gz
xsel:HITOMI-SGD1-CC_NORMAL1 > extract events
xsel:HITOMI-SGD1-CC_NORMAL1 > save events ah1000500ALL0sg1_p0ccALLrec_cl.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > extract spectrum
xsel:HITOMI-SGD1-CC_NORMAL1 > plot spectrum
xsel:HITOMI-SGD1-CC_NORMAL1 > extract curve
xsel:HITOMI-SGD1-CC_NORMAL1 > plot curve

```

(2) Create deadtime-corrected spectra and lightcurves using hxisgddtime

(a) Extract the combined (over sequence) spectrum and light curve for each individual camera.

```

xselect
xsel:SUZAKU > read events
..../100050020/sgd/event_cl/ah100050020sg1_p0cc1rec_cl.evt.gz
xsel:SUZAKU > read events
..../100050030/sgd/event_cl/ah100050030sg1_p0cc1rec_cl.evt.gz
xsel:SUZAKU > read events
..../100050040/sgd/event_cl/ah100050040sg1_p0cc1rec_cl.evt.gz
xsel:HITOMI-SGD1-CC_NORMAL1 > extract spectrum
xsel:HITOMI-SGD1-CC_NORMAL1 > save spectrum ah1000500ALL0sg1_p0cc1rec_cl.pi
xsel:HITOMI-SGD1-CC_NORMAL1 > extract curve
xsel:HITOMI-SGD1-CC_NORMAL1 > save curve ah1000500ALL0sg1_p0cc1rec_cl.lc
xsel:HITOMI-SGD1-CC_NORMAL1 > clear all
xsel:HITOMI-SGD1-CC_NORMAL1 > read events
..../100050020/sgd/event_cl/ah100050020sg1_p0cc2rec_cl.evt.gz
xsel:HITOMI-SGD1-CC_NORMAL1 > read events
..../100050030/sgd/event_cl/ah100050030sg1_p0cc2rec_cl.evt.gz
xsel:HITOMI-SGD1-CC_NORMAL1 > read events
..../100050040/sgd/event_cl/ah100050040sg1_p0cc2rec_cl.evt.gz

```

```

xsel: HITOMI-SGD1-CC_NORMAL1 > extract spectrum
xsel: HITOMI-SGD1-CC_NORMAL1 > save spectrum ah1000500ALL0sg1_p0cc2rec_cl.pi
xsel: HITOMI-SGD1-CC_NORMAL1 > extract curve
xsel: HITOMI-SGD1-CC_NORMAL1 > save curve ah1000500ALL0sg1_p0cc2rec_cl.lc
xsel: HITOMI-SGD1-CC_NORMAL1 > clear all
xsel: HITOMI-SGD1-CC_NORMAL1 > read events
..../100050020/sgd/event_cl/ah100050020sg1_p0cc3rec_cl.evt.gz
xsel: HITOMI-SGD1-CC_NORMAL1 > read events
..../100050030/sgd/event_cl/ah100050030sg1_p0cc3rec_cl.evt.gz
xsel: HITOMI-SGD1-CC_NORMAL1 > read events
..../100050040/sgd/event_cl/ah100050040sg1_p0cc3rec_cl.evt.gz
xsel: HITOMI-SGD1-CC_NORMAL1 > extract spectrum
xsel: HITOMI-SGD1-CC_NORMAL1 > save spectrum ah1000500ALL0sg1_p0cc3rec_cl.pi
xsel: HITOMI-SGD1-CC_NORMAL1 > extract curve
xsel: HITOMI-SGD1-CC_NORMAL1 > save curve ah1000500ALL0sg1_p0cc3rec_cl.lc

```

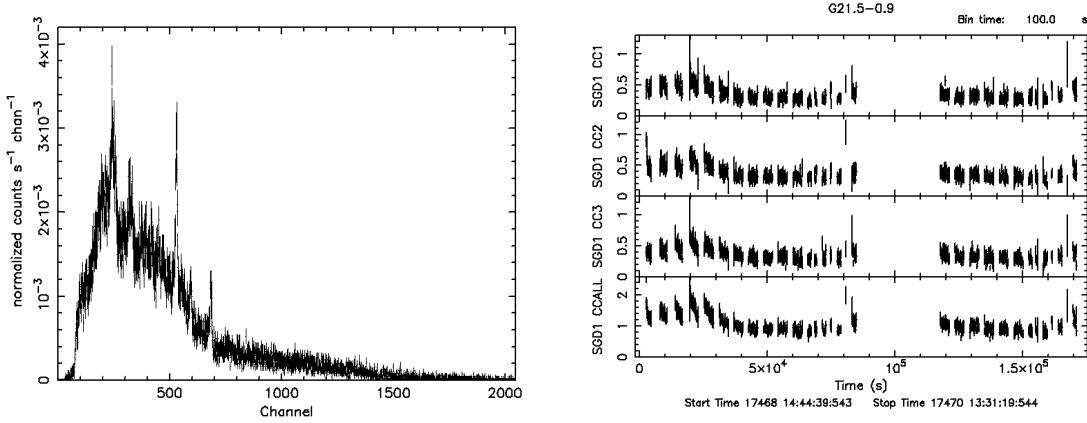


Figure 8: SGD1 summed spectrum and lightcurves (individual cameras and total) for sequences ah100050010, ah100050020, ah100050030, and ah100050040 plotted using XSPEC and lcview.

(b) Merge the pseudo-event files, including their GTI extensions:

```

ftmerge
'..../100050020/sgd/event_cl/ah100050020sg1_p0cc1recpse_cl.evt.gz,..../100050030/sg
d/event_cl/ah100050030sg1_p0cc1recpse_cl.evt.gz,..../100050040/sgd/event_cl/ah100
050040sg1_p0cc1recpse_cl.evt.gz' ah1000500ALL0sg1_p0cc1recpse_cl.evt

ahgtigen infile=None outfile=ah1000500ALL0sg1_p0cc1recpse_cl.gti
gtifile=@ah10005002340sg1_p0cc1recpse_cl.gti.lst gtiexpr=None mergegti=OR

```

where ah10005002340sg1_p0cc1recpse_cl.gti.lst is a text file listing all GTI extensions:

```

..../100050020/sgd/event_cl/ah100050020sg1_p0cc1recpse_cl.evt.gz+2
..../100050030/sgd/event_cl/ah100050030sg1_p0cc1recpse_cl.evt.gz+2
..../100050040/sgd/event_cl/ah100050040sg1_p0cc1recpse_cl.evt.gz+2

```

```
ftdelhdu 'ah1000500ALL0sg1_p0cc1recpse_cl.evt[GTI]' none confirm=YES
```

```
ftappend 'ah1000500ALL0sg1_p0cc1recpse_cl.gti[GTI]'
```

```
ah1000500ALL0sg1_p0cc1recpse_cl.evt
```

```
fthedit ah1000500ALL0sg1_p0cc1recpse_cl.evt+2 INSTRUME a SGD1
```

```
fthedit ah1000500ALL0sg1_p0cc1recpse_cl.evt+2 DETNAM a CC1
```

```
ftmerge
'..../100050020/sgd/event_cl/ah100050020sg1_p0cc2recpse_cl.evt.gz,..../100050030/sg
d/event_cl/ah100050030sg1_p0cc2recpse_cl.evt.gz,..../100050040/sgd/event_cl/ah100
050040sg1_p0cc2recpse_cl.evt.gz' ah1000500ALL0sg1_p0cc2recpse_cl.evt
```

```

ahgtigen infile=NONE outfile=ah1000500ALL0sg1_p0cc2recpse_cl.gti
gtifile=@ah10005002340sg1_p0cc2recpse_cl.gti.lst gtiexpr=NONE mergegti=OR

where ah10005002340sg1_p0cc2recpse_cl.gti.lst is a text file listing all GTI extensions:

..../100050020/sgd/event_cl/ah100050020sg1_p0cc2recpse_cl.evt.gz+2
..../100050030/sgd/event_cl/ah100050030sg1_p0cc2recpse_cl.evt.gz+2
..../100050040/sgd/event_cl/ah100050040sg1_p0cc2recpse_cl.evt.gz+2

ftdelhdu 'ah1000500ALL0sg1_p0cc2recpse_cl.evt[GTI]' none confirm=YES

ftappend 'ah1000500ALL0sg1_p0cc2recpse_cl.gti[GTI]'
ah1000500ALL0sg1_p0cc2recpse_cl.evt

fthedit ah1000500ALL0sg1_p0cc2recpse_cl.evt+2 INSTRUME a SGD1
fthedit ah1000500ALL0sg1_p0cc2recpse_cl.evt+2 DETNAM a CC2

ftmerge
'..../100050020/sgd/event_cl/ah100050020sg1_p0cc3recpse_cl.evt.gz,..../100050030/sg
d/event_cl/ah100050030sg1_p0cc3recpse_cl.evt.gz,..../100050040/sgd/event_cl/ah100
050040sg1_p0cc3recpse_cl.evt.gz' ah1000500ALL0sg1_p0cc3recpse_cl.evt

ahgtigen infile=NONE outfile=ah1000500ALL0sg1_p0cc3recpse_cl.gti
gtifile=@ah10005002340sg1_p0cc3recpse_cl.gti.lst gtiexpr=NONE mergegti=OR

where ah10005002340sg1_p0cc3recpse_cl.gti.lst is a text file listing all GTI extensions:

..../100050020/sgd/event_cl/ah100050020sg1_p0cc3recpse_cl.evt.gz+2
..../100050030/sgd/event_cl/ah100050030sg1_p0cc3recpse_cl.evt.gz+2
..../100050040/sgd/event_cl/ah100050040sg1_p0cc3recpse_cl.evt.gz+2

ftdelhdu 'ah1000500ALL0sg1_p0cc3recpse_cl.evt[GTI]' none confirm=YES

ftappend 'ah1000500ALL0sg1_p0cc3recpse_cl.gti[GTI]'
ah1000500ALL0sg1_p0cc3recpse_cl.evt

fthedit ah1000500ALL0sg1_p0cc3recpse_cl.evt+2 INSTRUME a SGD1
fthedit ah1000500ALL0sg1_p0cc3recpse_cl.evt+2 DETNAM a CC3

(c) Apply the deadtime correction to each camera

hxisgddtime infile=ah1000500ALL0sg1_p0cc1recpse_cl.evt
inlcfile=ah1000500ALL0sg1_p0cc1rec_cl.lc
inspecfile=ah1000500ALL0sg1_p0cc1rec_cl.pi
outlcfile=ah1000500ALL0sg1_p0cc1rec_dtime.lc
outfile=ah1000500ALL0sg1_p0cc1rec_dtime.pi
gtifile=ah1000500ALL0sg1_p0cc1rec_cl.evt chatter=2 clobber=yes

mv hxisgddtime.log hxisgddtime_ah1000500ALL0sg1cc1.log

hxisgddtime infile=ah1000500ALL0sg1_p0cc2recpse_cl.evt
inlcfile=ah1000500ALL0sg1_p0cc2rec_cl.lc
inspecfile=ah1000500ALL0sg1_p0cc2rec_cl.pi
outlcfile=ah1000500ALL0sg1_p0cc2rec_dtime.lc
outfile=ah1000500ALL0sg1_p0cc2rec_dtime.pi
gtifile=ah1000500ALL0sg1_p0cc2rec_cl.evt chatter=2 clobber=yes

mv hxisgddtime.log hxisgddtime_ah1000500ALL0sg1cc2.log

hxisgddtime infile=ah1000500ALL0sg1_p0cc3recpse_cl.evt
inlcfile=ah1000500ALL0sg1_p0cc3rec_cl.lc
inspecfile=ah1000500ALL0sg1_p0cc3rec_cl.pi

```

```

outlcfile=ah1000500ALL0sg1_p0cc3rec_dtime.lc
outfile=ah1000500ALL0sg1_p0cc3rec_dtime.pi
gtifile=ah1000500ALL0sg1_p0cc3rec_cl.evt chatter=2 clobber=yes

mv hxisgddtime.log hxisgddtime_ah1000500ALL0sg1cc3.log

```

(d) Add the individual spectra, setting the EXPOSURE keyword to the average of the three individual spectra.

```

mathpha
expr=ah1000500ALL0sg1_p0cc1rec_dtime.pi+ah1000500ALL0sg1_p0cc2rec_dtime.pi+ah10
0500ALL0sg1_p0cc3rec_dtime.pi units=C
outfil=ah1000500ALL0sg1_p0ccALLrec_dtime.pi exposure=42974 areascal=%
backscal=% ncomments=0

```

SXI

All newly created output files in this section are placed in the /full/path/to/data/sxi_products directory

```

cd /full/path/
cd data/products_sxi

```

Due to differences in the number of bad pixels between OBSIDs, the SXI event data cannot be combined in the same way as the other instruments. Instead, spectra, RMFs, exposure maps, and ARFs must be generated for each OBSID separately and then simultaneously combined at the end (see next section). As stated above, the steps for sequence 100050020 are repeated for 100050010, 100050030, and 100050040 to create source and background spectra for all sequences.

SXS

All newly created output files in this section are placed in the /full/path/to/data/sxs_products directory

```

cd /full/path/
cd data/products_sxs

i) combine the event files in xselect

xselect
xsel:SUZAKU > read events
..../100050010/sxs/event_cl/ah100050010sxs_p0px1010_cl.evt.gz
xsel:HIKOMI-SXS-PX_NORMAL > read events
..../100050020/sxs/event_cl/ah100050020sxs_p0px1010_cl.evt.gz
xsel:HIKOMI-SXS-PX_NORMAL > read events
..../100050030/sxs/event_cl/ah100050030sxs_p0px1010_cl.evt.gz
xsel:HIKOMI-SXS-PX_NORMAL > read events
..../100050040/sxs/event_cl/ah100050040sxs_p0px1010_cl.evt.gz
xsel:HIKOMI-SXS-PX_NORMAL > extract events
xsel:HIKOMI-SXS-PX_NORMAL > save events ah1000500ALL0sxs_p0px1010_cl.evt

```

ii) apply the extra rise-time screening

```

ftselect infile='ah1000500ALL0sxs_p0px1010_cl.evt[events]'
outfile=ah1000500ALL0sxs_p0px1010_cl2.evt
expression="(PI>=400)&&((RISE_TIME>=40 && RISE_TIME<=60 &&
ITYPE<4) || (ITYPE==4))"

```

Note that the current pipeline screening already excludes events with PI<600.

```

iii) extract the spectrum

ftmerge
'../100050010/auxil/ah100050010.ehk.gz,../100050020/auxil/ah100050020.ehk.gz,..
/100050030/auxil/ah100050030.ehk.gz,../100050040/auxil/ah100050040.ehk.gz'
ah1000500ALL0.ehk

sxsregext infile=ah1000500ALL0sxs_p0px1010_cl2.evt regmode=SKY
region=../../regions/region_SXI_100050012340.reg resolist=0
outroot=ah1000500ALL0sxs_region_SXS_det outexp=ah1000500ALL0sxs.expo
ehkfile=ah1000500ALL0.ehk delta=0.25 numphi=4 clobber=yes

```

or, equivalently,

```

xsel:SUZAKU > read events ah1000500ALL0sxs_p0px1010_cl2.evt
xsel:HIKOMI-SXS-PX_NORMAL > filter column "PIXEL=0:11,13:35"
xsel:HIKOMI-SXS-PX_NORMAL > filter GRADE "0:0"
xsel:HIKOMI-SXS-PX_NORMAL > filter pha_cutoff 4000 20000
xsel:HIKOMI-SXS-PX_NORMAL > extract image
xsel:HIKOMI-SXS-PX_NORMAL > save image ah1000500ALL0sxs_p0px1010_cl2.img
xsel:HIKOMI-SXS-PX_NORMAL > plot image
xsel:HIKOMI-SXS-PX_NORMAL > clear pha_cutoff
xsel:HIKOMI-SXS-PX_NORMAL > extract spectrum
xsel:HIKOMI-SXS-PX_NORMAL > save spectrum ah1000500ALL0sxs_p0px1010_cl2_HP.pi
xsel:HIKOMI-SXS-PX_NORMAL > extract curve
xsel:HIKOMI-SXS-PX_NORMAL > save curve ah1000500ALL0sxs_p0px1010_cl2_HP.lc
xsel:HIKOMI-SXS-PX_NORMAL > plot curve

```

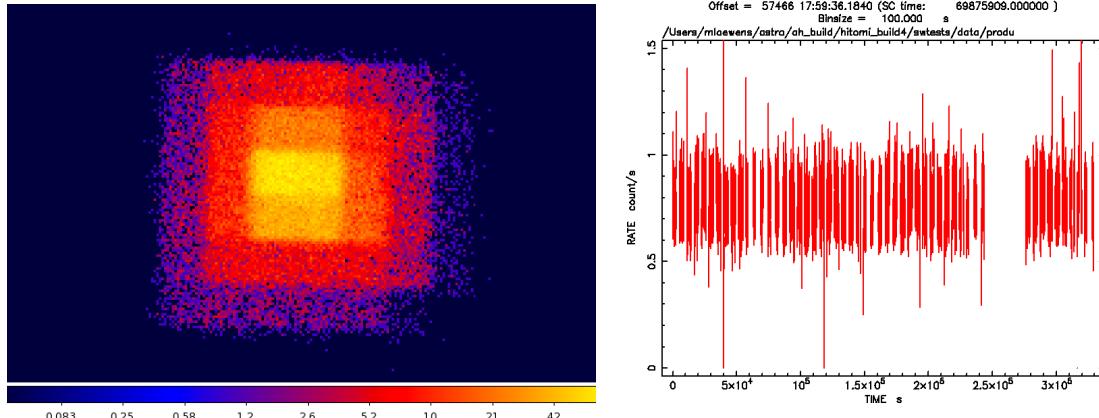


Figure 9: Combined SXS HP 2-10 keV SKY coordinate image, and lightcurve.

Generating Exposure Map, RMF, and ARF

100050020

HXI

All newly created output files in this section are placed in the /full/path/to/data/hxi_products directory

```

cd /full/path/
cd data/products_hxi

```

(1) Create an exposure map for each HXI

The exposure maps generated here are used in the two examples below to make both the RSP and flat field for the HXI. Note: The exposure maps are created with the parameters `delta=20.0`, `numphi=1` to assure that the map includes only a single attitude bin, i.e. assuming that the attitude is stable relative to the size of the PSF and extraction region.

HXI1

```
ahexpmap ehkfile=../100050020/auxil/ah100050020.ehk.gz
gtifile=../100050020/hxi/event_cl/ah100050020hx1_p0camrec_cl.evt.gz
instrume=HXI1 badimgfile=NONE pixgtifile=NONE
outfile=ah100050020hx1_p0camrec.expo outmapttype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=10.0 eperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100050020hx1_p0camrec.log
```

HXI2

```
ahexpmap ehkfile=../100050020/auxil/ah100050020.ehk.gz
gtifile=../100050020/hxi/event_cl/ah100050020hx2_p0camrec_cl.evt.gz
instrume=HXI2 badimgfile=NONE pixgtifile=NONE
outfile=ah100050020hx2_p0camrec.expo outmapttype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=10.0 eperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100050020hx2_p0camrec.log
```

(2) Create an RSP for each HXI (~24 min)

Make RSP for HXI1 and HXI2, sampling=120, point source at center of extraction region `region_HXI_100050012340.reg`. In general, the `source_ra` and `source_dec` parameters should be the coordinates of the center of the source in the image, which are not necessarily the same as the actual source coordinates. Here we use the center of the spectral extraction region. An on-axis point source response can be constructed by setting the source coordinates to the single value of `RANOMXP` and `DECNOMXP` in the first extension of the exposure map. The runtime estimated above is for the case above where the exposure map has a single attitude bin. The parameter `numphoton` may need to be decreased to accommodate a larger number of attitude bins.

HXI1

```
aharfgen xrtevtfile=raytrace_ah100050020hx1_p0camrec.fits source_ra=278.3889
source_dec=-10.5691 telescop=HITOMI instrume=HXI1
emapfile=ah100050020hx1_p0camrec.expo
dattfile=../100050020/hxi/event_uf/ah100050020hx1.att.gz regmode=SKY
regionfile=../../regions/region_HXI_100050012340.reg sampling=120
sourcetype=point erange="4.0 80.0" outfile=ah100050020hx1_rt
filtoffsetfile=../100050020/hxi/event_uf/ah100050020hx1_cms.fits.gz
numphoton=10000 minphoton=1 teldeffile=CALDB qefile=CALDB rmffile=CALDB
onaxisffile=CALDB onaxiscfle=CALDB mirrorfile=CALDB obstructfile=CALDB
frontreffile=CALDB pcolreffile=CALDB scatterfile=CALDB seed=7 clobber=yes
chatter=2 mode=h logfile=make_arf_ah100050020hx1_p0camrec.log
```

HXI2

```
aharfgen xrtevtfile=raytrace_ah100050020hx2_p0camrec.fits source_ra=278.3889
source_dec=-10.5691 telescop=HITOMI instrume=HXI2
```

```

emapfile=ah100050020hx2_p0camrec.expo
dattfile=../100050020/hxi/event_uf/ah100050020hx2.att.gz regmode=SKY
regionfile=../../regions/region_HXI_100050012340.reg sampling=120
sourcetype=point erange="4.0 80.0" outfile=ah100050020hx2_rt
filtoffsetfile=../100050020/hxi/event_uf/ah100050020hx2_cms.fits.gz
numphoton=10000 minphoton=1 teldeffile=CALDB qefile=CALDB rmffile=CALDB
onaxisffile=CALDB onaxiscfle=CALDB mirrorfile=CALDB obstructfile=CALDB
frontreffile=CALDB pcolreffile=CALDB scatterfile=CALDB seed=7 clobber=yes
chatter=2 mode=h logfile=make_arf_ah100050020hx2_p0camrec.log

```

(3) Create flat field efficiency images for each HXI (~8 min)

HXI1

```

hxirspeffimg telescop=HITOMI instrume=HXI1
emapfile=ah100050020hx1_p0camrec.expo
xrtevtfile=raytrace_ah100050020hx1_p0camrec.fits onaxisffile=CALDB
onaxiscfle=CALDB regionfile=NONE
dattfile=../100050020/hxi/event_uf/ah100050020hx1.att.gz stopsyst=SKY
sampling=40 erange="4.0 80.0"
filtoffsetfile=../100050020/hxi/event_uf/ah100050020hx1_cms.fits.gz
outflatfile=ah100050020hx1_flatfield.fits vigfile=CALDB outmaptype=EFFICIENCY
qefile=CALDB rmffile=CALDB clobber=yes chatter=2 mode=h
logfile=make_flat_ah100050020hx1_p0camrec.log

```

HXI2

```

time hxirspeffimg telescop=HITOMI instrume=HXI2
emapfile=ah100050020hx2_p0camrec.expo
xrtevtfile=raytrace_ah100050020hx2_p0camrec.fits onaxisffile=CALDB
onaxiscfle=CALDB regionfile=NONE
dattfile=../100050020/hxi/event_uf/ah100050020hx2.att.gz stopsyst=SKY
sampling=40 erange="4.0 80.0"
filtoffsetfile=../100050020/hxi/event_uf/ah100050020hx2_cms.fits.gz
outflatfile=ah100050020hx2_flatfield.fits vigfile=CALDB outmaptype=EFFICIENCY
qefile=CALDB rmffile=CALDB clobber=yes chatter=2 mode=h
logfile=make_flat_ah100050020hx2_p0camrec.log

```

These commands produce the images shown below:

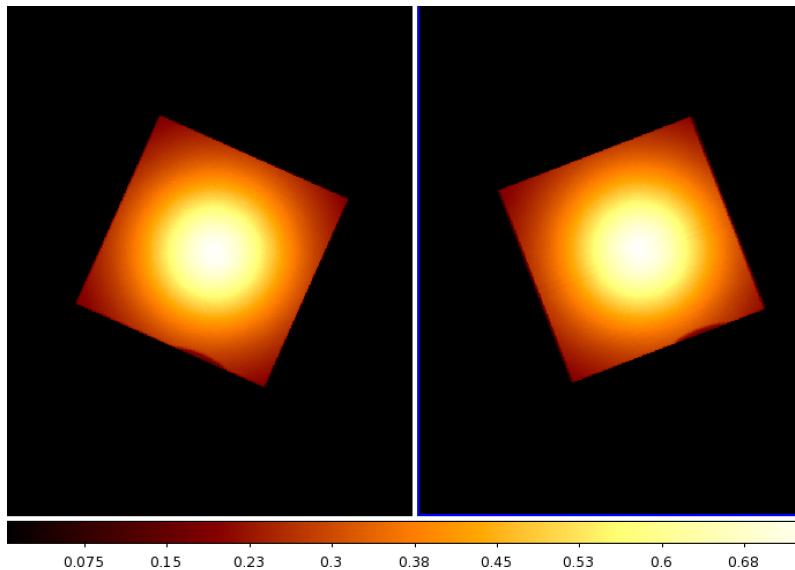


Figure 10: HXI1 (left) and HXI2 (right) flat field images for sequence 100050020.

SGD

All newly created output files in this section are placed in the /full/path/to/data/hxi_products directory

```
cd /full/path/
```

```
cd data/products_sgd
```

All newly created output files in this section are placed in the /full/path/to/data/sgd_products directory

Create the individual response files for each SGD1 Compton camera, and co-add them. To construct an on-axis response, directly co-add the CALDB response files used as input to the SGD arf generator. Here we use the center of the spectral extraction region as the source coordinates.

```
sgdarfgen infile=ah100050020sg1_p0ccALLrec_dtime.pi
rspfile="$CALDB/data/hitomi/sgd/cpf/response/ah_sg1_cc1_20140101v001.rsp,$CALDB
/data/hitomi/sgd/cpf/response/ah_sg1_cc2_20140101v001.rsp,$CALDB/data/hitomi/sg
d/cpf/response/ah_sg1_cc3_20140101v001.rsp" outfile=outrsp_100050020
ra=278.3889 dec=-10.5691 sgdid=1 ccid=0 clobber=yes

addrmf
outrsp_100050020_sg1_cc1.rsp,outrsp_100050020_sg1_cc2.rsp,outrsp_100050020_sg
d1_cc3.rsp 1.0,1.0,1.0 ah100050020_sg1_ccALL.rsp
```

SXI

All newly created output files in this section are placed in the /full/path/to/data/sxi_products directory

```
cd /full/path/
```

```
cd data/products_sxi
```

(1) Create an RMF for the source spectrum

Normal mode

```
sxirmf infile=ah100050020sxi_p0100004b0_cl.pi
outfile=ah100050020sxi_p0100004b0_cl.rmf clobber=yes mode=h1
```

MZDYE

```
sxirmf infile=ah100050020sxi_p0100004b1_cl.pi
outfile=ah100050020sxi_p0100004b1_cl.rmf clobber=yes mode=h1
```

(2) Create an Exposure Map for the source spectrum

The exposure maps generated here are used in the two examples below to make both the ARF and flat field for the SXI. Note: The exposure maps are created with the parameters delta=20.0, numphi=1 to assure that the map includes only a single attitude bin, i.e. assuming that the attitude is stable relative to the size of the PSF and extraction region.

Normal mode

```
ahexpmap ehkfile=../100050020/auxil/ah100050020.ehk.gz
gtifile=../100050020/sxi/event_cl/ah100050020sxi_p0100004b0_cl.evt.gz
instrume=SXI
badimgfile=../100050020/sxi/event_uf/ah100050020sxi_p0100004b0.bimg.gz
```

```

pixgtifile=../100050020/sxi/event_uf/ah100050020sxi_a0100004b0.fpix.gz
outfile=ah100050020sxi_p0100004b0.expo outmappytype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100050020sxi_a0100004b0.log

```

MZDYE

```

ahexpmap ehkfile=../100050020/auxil/ah100050020.ehk.gz
gtifile=../100050020/sxi/event_cl/ah100050020sxi_p0100004b1_cl.evt.gz
instrume=SXI
badimgfile=../100050020/sxi/event_uf/ah100050020sxi_p0100004b1.bimg.gz
pixgtifile=../100050020/sxi/event_uf/ah100050020sxi_a0100004b1.fpix.gz
outfile=ah100050020sxi_p0100004b1.expo outmappytype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100050020sxi_a0100004b1.log

```

(3) Create an ARF for the source spectrum (~23 min)

In general, the `source_ra` and `source_dec` parameters should be the coordinates of the center of the source in the image, which are not necessarily the same as the actual source coordinates. Here we use the center of the spectral extraction region. The runtime estimated above is for the case above where the exposure map has a single attitude bin. The parameter `numphoton` may need to be decreased to accommodate a larger number of attitude bins.

Normal mode

```

aharfgen xrtevtfile=raytrace_ah100050020sxi_p0100004b0_ptsrc_evt.fits
source_ra=278.3889 source_dec=-10.5691 telescop=HITOMI instrume=SXI
emapfile=ah100050020sxi_p0100004b0.expo regmode=SKY
regionfile=../../regions/region_SXI_100050012340.reg sourcetype=POINT
rmffile=ah100050020sxi_p0100004b0_cl.rmf erange="0.5 16.0 0 0"
outfile=ah100050020sxi_p0100004b0_rt.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamofile=CALDB onaxisffile=CALDB
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB seed=7 clobber=yes
chatter=2 mode=h logfile=make_arf_ah100050020sxi_p0100004b0.log

```

MZDYE

```

aharfgen xrtevtfile=raytrace_ah100050020sxi_p0100004b1_ptsrc_evt.fits
source_ra=278.3889 source_dec=-10.5691 telescop=HITOMI instrume=SXI
emapfile=ah100050020sxi_p0100004b1.expo regmode=SKY
regionfile=../../regions/region_SXI_100050012340.reg sourcetype=POINT
rmffile=ah100050020sxi_p0100004b1_cl.rmf erange="0.5 16.0 0 0"
outfile=ah100050020sxi_p0100004b1_rt.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamofile=CALDB onaxisffile=CALDB
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB seed=7 clobber=yes
chatter=2 mode=h logfile=make_arf_ah100050020sxi_p0100004b1.log

```

(4) Create an efficiency map (flat field)

Normal mode

```

ahexpmap ehkfile=../100050020/auxil/ah100050020.ehk.gz
gtifile=../100050020/sxi/event_cl/ah100050020sxi_p0100004b0_cl.evt.gz
instrume=SXI
badimgfile=../100050020/sxi/event_uf/ah100050020sxi_p0100004b0.bimg.gz
pixgtifile=../100050020/sxi/event_uf/ah100050020sxi_a0100004b0.fpix.gz
outfile=ah100050020sxi_p0100004b0.flat outmaptype=EFFICIENCY delta=20.0
numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_flat_ah100050020sxi_a0100004b0.log

```

MZDYE

```

ahexpmap ehkfile=../100050020/auxil/ah100050020.ehk.gz
gtifile=../100050020/sxi/event_cl/ah100050020sxi_p0100004b1_cl.evt.gz
instrume=SXI
badimgfile=../100050020/sxi/event_uf/ah100050020sxi_p0100004b1.bimg.gz
pixgtifile=../100050020/sxi/event_uf/ah100050020sxi_a0100004b1.fpix.gz
outfile=ah100050020sxi_p0100004b1.flat outmaptype=EFFICIENCY delta=20.0
numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_flat_ah100050020sxi_a0100004b1.log

```

These commands produces the images shown below:

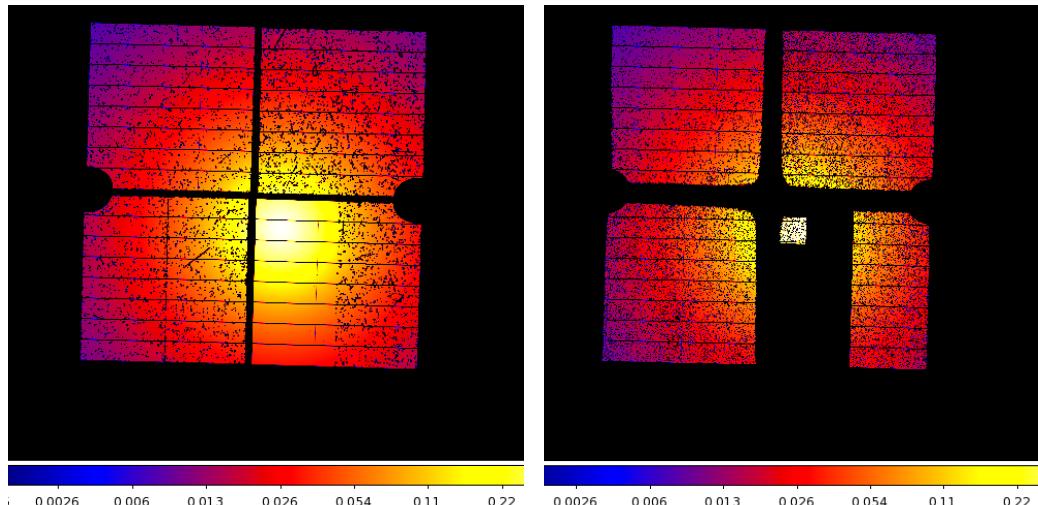


Figure 11: SXI flat field images for sequence 100050020 (left: Normal, right: MZDYE).

(5) Correct the BACKSCAL keyword in the SXI spectra

Xselect writes a BACKSCAL keyword in the header of extracted spectra to properly scale the background subtraction in XSPEC. However, it only accounts for the fraction of the area covered by the extraction region, not the number of good pixels. Many pixels in SXI data are affected by cosmic-ray echo or light leak and need to be properly excluded from BACKSCAL. The following should be done for both the 'Normal' and 'MZDYE' source and background spectra.

- Read the exposure map into XIMAGE and use the "counts" command to obtain the number of pixel*seconds within the background region.

```

ximage
[XIMAGE> read/rebin=1/szx=2430/szy=2430 ah100050020sxi_p0100004b0_c1.expo
[XIMAGE> counts .../regions/region_SXI_100050012340.reg
Total          Area          Area      Average      Average
  (count)    (img-pix)    (det-pix)  (per img-pix)  (per det-pix)
# 3.4299667E+08   22622.000     22622.000      15162.084      15162.084

```

b) Get the good exposure time from the exposure map.

```

fkeypar 'ah100050020sxi_p0100004b0.expo[1]' EXPOSURE
pget fkeypar value
15998.4012296647

```

c) Divide "Total counts" reported by XIMAGE by the exposure time to get the total number of good pixels.

```
N_goodpix = 3.4299667E+08 / 15998.4012296647 = 21439.43417
```

Note that it is fractional, because some of the pixels in SKY coordinates have fractional exposure due to (even small) attitude wobbles (e.g., that location on the sky moves in and out of a bad pixel or charge injection row).

d) Divide the number of good pixels by the total number of pixels in X,Y coordinates (2430x2430) and set the BACKSCAL keyword.

```

BACKSCAL = N_goodpix / (2430)^2 = 0.003630787
ftthedit 'ah100050020sxi_p0100004b0_c1.pi[1]' BACKSCAL a 0.003630787

```

Steps 1-5 are repeated for sequences ah100050010, ah100050030, and ah100050040.

SXS

All newly created output files in this section are placed in the /full/path/to/data/sxs_products directory

```

cd /full/path/
cd data/products_sxs

```

(1) Generate the RMF

Here we use the “small” size option (Gaussian core only). Change whichrmf parameter to “m” to include exponential tail to low energies, and to “l” to include escape peaks. The DET coordinate region file ah100050020sxs_region_SXS_det.reg created by sxsregext is input.

```

sxsmkrmf infile=ah100050020sxs_p0px1010_c12.evt
outfile=ah100050020_sxs_c12_HP_small.rmf resolist=0 regmode=det
regionfile=ah100050020sxs_region_SXS_det.reg whichrmf=s

```

We also construct an SXS RMF using the “x-large” option which is necessary to study the spectrum below 2 keV. The threshold may be increased from 1.0e-9 to 1.0e-6 to reduce the size of the output file.

```

sxsmkrmf infile=ah100050020sxs_p0px1010_c12.evt
outfile=ah100050020_sxs_c12_HP_xlarge.rmf resolist=0 regmode=det
regionfile=ah100050020sxs_region_SXS_det.reg whichrmf=x

```

(2) Regenerate the SXS exposure maps

Note: The exposure maps created with sxsregexp are replaced using the parameters delta=20.0, numphi=1 to assure that map includes only a single attitude bin. This assumes that the attitude is stable relative to the size of the PSF and extraction region. We also account for the lost event gti per pixel here by inputting the pixgti file ah100050020sxs_px1010_exp.gti and setting the pixgtifile parameter accordingly -- this should be done if the lost event gti are not used in the screening (as in the standard pipeline).

```
ahexpmap ehkfile=../100050020/auxil/ah100050020.ehk.gz
gtifile=ah100050020sxs_p0px1010_cl2.evt instrume=SXS badimgfile=NONE
pixgtifile=../100050020/sxs/event_uf/ah100050020sxs_px1010_exp.gti.gz
outfile=ah100050020sxs_p0px1010.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100050020sxs_p0px1010.log
```

3) Generate the SXS ARF (~36 min)

The runtime estimated above is for the case above where the exposure map has a single attitude bin. The parameter numphoton may need to be decreased to accommodate larger number of attitude bins.

```
aaharfgen xrtevtfle=raytrace_ah100050020sxs_p0px1010.fits source_ra=278.3889
source_dec=-10.5691 telescop=HITOMI instrume=SXS
emapfile=ah100050020sxs_p0px1010.expo regmode=DET
regionfile=ah100050020sxs_region_SXS_det.reg sourcetype=POINT
rmffile=ah100050020_sxs_cl2_HP_small.rmf erange="0.5 17.0 0 0"
outfile=ah100050020sxs_p0px1010_rt.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamofile=CALDB obffile=CALDB fwfile=CALDB
gatevalvefile=CALDB onaxisffile=CALDB onaxiscfle=CALDB mirrorfile=CALDB
obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB
scatterfile=CALDB seed=7 clobber=yes chatter=2 mode=h
logfile=make_arf_ah100050020sxs_p0px1010.log
```

Note that the source_ra and source_dec are taken from the region file region_SXI_100050020.reg, i.e. an estimate of the source coordinates based on the SXI image. The region file used is the one in DET coordinates created above by sxsregexp.

100050010, 100050020, 100050030, 100050040 COMBINED

HXI

```
cd /full/path/
cd data/products_hxi
```

(1) Merge the necessary files from each sequence

```
ftmerge
'../100050010/auxil/ah100050010.ehk.gz,../100050020/auxil/ah100050020.ehk.gz,..
/100050030/auxil/ah100050030.ehk.gz,../100050040/auxil/ah100050040.ehk.gz'
ah1000500ALL0.ehk

ftmerge
'../100050010/hxi/event_uf/ah100050010hx1.att.gz,../100050020/hxi/event_uf/ah10
050020hx1.att.gz,../100050030/hxi/event_uf/ah100050030hx1.att.gz,../100050040/
hxi/event_uf/ah100050040hx1.att.gz' ah1000500ALL0hx1.att

ftmerge
'../100050010/hxi/event_uf/ah100050010hx2.att.gz,../100050020/hxi/event_uf/ah10
```

```

0050020hx2.att.gz,.../100050030/hxi/event_uf/ah100050030hx2.att.gz,.../100050040/
hxi/event_uf/ah100050040hx2.att.gz' ah1000500ALL0hx2.att

ftmerge
'../100050010/hxi/event_uf/ah100050010hx1_cms.fits.gz,.../100050020/hxi/event_uf
/ah100050020hx1_cms.fits.gz,.../100050030/hxi/event_uf/ah100050030hx1_cms.fits.g
z,.../100050040/hxi/event_uf/ah100050040hx1_cms.fits.gz'
ah1000500ALL0hx1_cms.fits

ftmerge
'../100050010/hxi/event_uf/ah100050010hx2_cms.fits.gz,.../100050020/hxi/event_uf
/ah100050020hx2_cms.fits.gz,.../100050030/hxi/event_uf/ah100050030hx2_cms.fits.g
z,.../100050040/hxi/event_uf/ah100050040hx2_cms.fits.gz'
ah1000500ALL0hx2_cms.fits

```

The merged event GTI created above are used here.

```
ah1000500ALL0hx1_p0camrec_cl.gti and ah1000500ALL0hx2_p0camrec_cl.gti
```

(2) Create an exposure map for the combined HXI

The exposure maps generated here are used in the two examples below to make both the RSP and flat field for the HXI. Note: The exposure maps are created with the parameters `delta=20.0`, `numphi=1` to assure that the map includes only a single attitude bin, i.e. assuming that the attitude is stable relative to the size of the PSF and extraction region.

HXI1

```

ahexpmap ehkfile=ah1000500ALL0.ehk gtifile=ah1000500ALL0hx1_p0camrec_cl.gti
instrume=HXI1 badimgfile=NONE pixgtifile=NONE
outfile=ah1000500ALL0hx1_p0camrec.expo outmaptyp=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=10.0 eperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah1000500all0hx1_p0camrec.log

```

HXI2

```

ahexpmap ehkfile=ah1000500ALL0.ehk gtifile=ah1000500ALL0hx2_p0camrec_cl.gti
instrume=HXI1 badimgfile=NONE pixgtifile=NONE
outfile=ah1000500ALL0hx2_p0camrec.expo outmaptyp=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=10.0 eperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah1000500all0hx2_p0camrec.log

```

(3) Create an RSP for the combined HXI (~29 min)

Make RSP for HXI1 and HXI2, sampling=120, point source at center of extraction region
`region_HXI_100050012340.reg`. In general, the `source_ra` and `source_dec` parameters should be the coordinates of the center of the source in the image, which are not necessarily the same as the actual source coordinates. Here we use the center of the spectral extraction region.

HXI1

```

aharfgen xrtevtfile=raytrace_ah1000500ALL0hx1_p0camrec.fits source_ra=278.3889
source_dec=-10.5691 telescop=HITOMI instrume=HXI1
emapfile=ah1000500ALL0hx1_p0camrec.expo dattfile=ah1000500ALL0hx1.att

```

```

regmode=SKY regionfile=../../regions/region_HXI_100050012340.reg sampling=120
sourcetype=point erange="4.0 80.0" outfile=ah1000500ALL0hx1_rt
filtoffsetfile=ah1000500ALL0hx1_cms.fits numphoton=10000 minphoton=1
teldeffile=CALDB qefile=CALDB rmffile=CALDB onaxisffile=CALDB onaxiscfile=CALDB
mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB pcolreffile=CALDB
scatterfile=CALDB clobber=yes chatter=2 mode=h seed=7
logfile=make_arf_ah1000500ALL0hx1_p0camrec.log

```

HXI2

```

aharfgen xrtevtfile=raytrace_ah1000500ALL0hx2_p0camrec.fits source_ra=278.3889
source_dec=-10.5691 telescop=HITOMI instrume=HXI2
emapfile=ah1000500ALL0hx2_p0camrec.expo dattfile=ah1000500ALL0hx2.att
regmode=SKY regionfile=../../regions/region_HXI_100050012340.reg sampling=120
sourcetype=point erange="4.0 80.0" outfile=ah1000500ALL0hx2_rt
filtoffsetfile=ah1000500ALL0hx2_cms.fits numphoton=10000 minphoton=1
teldeffile=CALDB qefile=CALDB rmffile=CALDB onaxisffile=CALDB onaxiscfile=CALDB
mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB pcolreffile=CALDB
scatterfile=CALDB clobber=yes chatter=2 mode=h seed=7
logfile=make_arf_ah1000500ALL0hx2_p0camrec.log

```

(4) Create flat field efficiency images for each HXI (~23 min)

HXI1

```

hxirspeffimg telescop=HITOMI instrume=HXI1
emapfile=ah1000500ALL0hx1_p0camrec.expo
xrtevtfile=raytrace_ah1000500ALL0hx1_p0camrec.fits onaxisffile=CALDB
onaxiscfile=CALDB regionfile=NONE dattfile=ah1000500ALL0hx1.att stopsyst=SKY
sampling=40 erange="4.0 80.0 10.0 50.0"
filtoffsetfile=ah1000500ALL0hx1_cms.fits
outflatfile=ah1000500ALL0hx1_flatfield.fits vigfile=CALDB outmapttype=EFFICIENCY
qefile=CALDB rmffile=CALDB chatter=2 mode=h
logfile=make_flat_ah1000500all0hx1_p0camrec.log

```

HXI2

```

hxirspeffimg telescop=HITOMI instrume=HXI2
emapfile=ah1000500ALL0hx2_p0camrec.expo
xrtevtfile=raytrace_ah1000500ALL0hx2_p0camrec.fits onaxisffile=CALDB
onaxiscfile=CALDB regionfile=NONE dattfile=ah1000500ALL0hx2.att stopsyst=SKY
sampling=40 erange="4.0 80.0 10.0 50.0"
filtoffsetfile=ah1000500ALL0hx2_cms.fits
outflatfile=ah1000500ALL0hx2_flatfield.fits vigfile=CALDB outmapttype=EFFICIENCY
qefile=CALDB rmffile=CALDB chatter=2 mode=h
logfile=make_flat_ah1000500all0hx2_p0camrec.log

```

SGD

All newly created output files in this section are placed in the /full/path/to/data/hxi_products directory

```

cd /full/path/
mkdir data/products_sgd
cd data/products_sgd

```

All newly created output files in this section are placed in the /full/path/to/data/sgd_products directory

Create the individual response files for each SGD1 Compton camera and each sequence, and co-add them with weights determined by the relative exposures for each sequence and each camera. To construct an on-

axis response, directly co-add the CALDB response files used as input to the SGD arf generator. Here we use the center of the SXI spectral extraction region as the source coordinates

```

sgdarfgen infile=ah100050020sg1_p0cc1rec_dtime.pi
rspfile="$CALDB/data/hitomi/sgd/cpf/response/ah_sg1_cc1_20140101v001.rsp,$CALDB
/data/hitomi/sgd/cpf/response/ah_sg1_cc2_20140101v001.rsp,$CALDB/data/hitomi/sg
d/cpf/response/ah_sg1_cc3_20140101v001.rsp" outfile=outrsp_100050020
ra=278.3889 dec=-10.5691 sgdid=1 ccid=0 clobber=yes

sgdarfgen infile=ah100050030sg1_p0cc1rec_dtime.pi
rspfile="$CALDB/data/hitomi/sgd/cpf/response/ah_sg1_cc1_20140101v001.rsp,$CALDB
/data/hitomi/sgd/cpf/response/ah_sg1_cc2_20140101v001.rsp,$CALDB/data/hitomi/sg
d/cpf/response/ah_sg1_cc3_20140101v001.rsp" outfile=outrsp_100050030
ra=278.3889 dec=-10.5691 sgdid=1 ccid=0 clobber=yes

sgdarfgen infile=ah100050040sg1_p0cc1rec_dtime.pi
rspfile="$CALDB/data/hitomi/sgd/cpf/response/ah_sg1_cc1_20140101v001.rsp,$CALDB
/data/hitomi/sgd/cpf/response/ah_sg1_cc2_20140101v001.rsp,$CALDB/data/hitomi/sg
d/cpf/response/ah_sg1_cc3_20140101v001.rsp" outfile=outrsp_100050040
ra=278.3889 dec=-10.5691 sgdid=1 ccid=0 clobber=yes

addrmf
outrsp_100050040_sgd1_cc1.rsp,outrsp_100050040_sgd1_cc2.rsp,outrsp_100050040_sg
d1_cc3.rsp,outrsp_100050030_sgd1_cc2.rsp,outrsp_100050030_sgd1_cc3.rsp,outrsp_1
00050030_sgd1_cc1.rsp,outrsp_100050020_sgd1_cc1.rsp,outrsp_100050020_sgd1_cc2.r
sp,outrsp_100050020_sgd1_cc3.rsp
0.389665844,0.387071252,0.390678084,0.541304044,0.541909061,0.542572253,0.06885
5587,0.069821287,0.068122586 ah1000500ALL0sg1_ccALL_dtime_wtd.rsp

```

SXI

Note that because the cosmic ray echo effect varies between sequences over the course of the observation, a single bad image file cannot be used below. In general this should be checked when deriving SXI spectral ARFs for combined sequences. If they differ as they do here, separate RMF and ARF files should be derived, as detailed above for sequence 100050020 and below for the remaining sequences. The spectra and responses should then be co-added, or individual spectra should be simultaneously fit.

```

cd /full/path/
cd data/products_sxi

```

(1) Create an RMF for each remaining sequence

Normal mode

```

sxirmf infile=ah100050010sxi_p0100004b0_cl.pi
outfile=ah100050010sxi_p0100004b0_cl.rmf clobber=yes mode=h1

sxirmf infile=ah100050030sxi_p0100004b0_cl.pi
outfile=ah100050030sxi_p0100004b0_cl.rmf clobber=yes mode=h1

sxirmf infile=ah100050040sxi_p0100004b0_cl.pi
outfile=ah100050040sxi_p0100004b0_cl.rmf clobber=yes mode=h1

```

MZDYE

```

sxirmf infile=ah100050010sxi_p0100004b1_cl.pi
outfile=ah100050010sxi_p0100004b1_cl.rmf clobber=yes mode=h1
sxirmf infile=ah100050030sxi_p0100004b1_cl.pi
outfile=ah100050030sxi_p0100004b1_cl.rmf clobber=yes mode=h1

```

```

sxirmf infile=ah100050040sxi_p0100004b1_cl.pi
outfile=ah100050040sxi_p0100004b1_cl.rmf clobber=yes mode=h1

```

(2) Create an exposure map for each remaining sequence

Normal mode

```

ahexpmap ehkfile=../100050010/auxil/ah100050010.ehk.gz
gtifile=../100050010/sxi/event_cl/ah100050010sxi_p0100004b0_cl.evt.gz
instrume=SXI
badimgfile=../100050010/sxi/event_uf/ah100050010sxi_p0100004b0.bimg.gz
pixgtifile=../100050010/sxi/event_uf/ah100050010sxi_a0100004b0.fpix.gz
outfile=ah100050010sxi_p0100004b0.expo outmapttype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100050010sxi_a0100004b0.log

ahexpmap ehkfile=../100050030/auxil/ah100050030.ehk.gz
gtifile=../100050030/sxi/event_cl/ah100050030sxi_p0100004b0_cl.evt.gz
instrume=SXI
badimgfile=../100050030/sxi/event_uf/ah100050030sxi_p0100004b0.bimg.gz
pixgtifile=../100050030/sxi/event_uf/ah100050030sxi_a0100004b0.fpix.gz
outfile=ah100050030sxi_p0100004b0.expo outmapttype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100050030sxi_a0100004b0.log

ahexpmap ehkfile=../100050040/auxil/ah100050040.ehk.gz
gtifile=../100050040/sxi/event_cl/ah100050040sxi_p0100004b0_cl.evt.gz
instrume=SXI
badimgfile=../100050040/sxi/event_uf/ah100050040sxi_p0100004b0.bimg.gz
pixgtifile=../100050040/sxi/event_uf/ah100050040sxi_a0100004b0.fpix.gz
outfile=ah100050040sxi_p0100004b0.expo outmapttype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100050040sxi_a0100004b0.log

```

MZDYE

```

ahexpmap ehkfile=../100050010/auxil/ah100050010.ehk.gz
gtifile=../100050010/sxi/event_cl/ah100050010sxi_p0100004b1_cl.evt.gz
instrume=SXI
badimgfile=../100050010/sxi/event_uf/ah100050010sxi_p0100004b1.bimg.gz
pixgtifile=../100050010/sxi/event_uf/ah100050010sxi_a0100004b1.fpix.gz
outfile=ah100050010sxi_p0100004b1.expo outmapttype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100050010sxi_a0100004b1.log

ahexpmap ehkfile=../100050030/auxil/ah100050030.ehk.gz
gtifile=../100050030/sxi/event_cl/ah100050030sxi_p0100004b1_cl.evt.gz
instrume=SXI
badimgfile=../100050030/sxi/event_uf/ah100050030sxi_p0100004b1.bimg.gz
pixgtifile=../100050030/sxi/event_uf/ah100050030sxi_a0100004b1.fpix.gz
outfile=ah100050030sxi_p0100004b1.expo outmapttype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB

```

```

obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100050030sxi_a0100004b1.log

ahexpmap ehkfile=../100050040/auxil/ah100050040.ehk.gz
gtifile=../100050040/sxi/event_cl/ah100050040sxi_p0100004b1_cl.evt.gz
instrume=SXI
badimgfile=../100050040/sxi/event_uf/ah100050040sxi_p0100004b1.bimg.gz
pixgtifile=../100050040/sxi/event_uf/ah100050040sxi_a0100004b1.fpix.gz
outfile=ah100050040sxi_p0100004b1.expo outmapttype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100050040sxi_a0100004b1.log

```

(3) Create an ARF for each remaining sequence

Here we use the center of the spectral extraction region as the source coordinates.

Normal mode

```

aharfgen xrtevtfile=raytrace_ah100050010sxi_p0100004b0_ptsrc_evt.fits
source_ra=278.3889 source_dec=-10.5691 telescop=HITOMI instrume=SXI
emapfile=ah100050010sxi_p0100004b0.expo regmode=SKY
regionfile=../../regions/region_SXI_100050012340.reg sourcetype=POINT
rmffile=ah100050010sxi_p0100004b0_cl.rmf erange="0.5 16.0 0 0"
outfile=ah100050010sxi_p0100004b0_rt.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamofile=CALDB onaxisffile=CALDB
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB seed=7 clobber=yes
chatter=2 mode=h logfile=make_arf_ah100050010sxi_p0100004b0.log

aharfgen xrtevtfile=raytrace_ah100050030sxi_p0100004b0_ptsrc_evt.fits
source_ra=278.3889 source_dec=-10.5691 telescop=HITOMI instrume=SXI
emapfile=ah100050030sxi_p0100004b0.expo regmode=SKY
regionfile=../../regions/region_SXI_100050012340.reg sourcetype=POINT
rmffile=ah100050030sxi_p0100004b0_cl.rmf erange="0.5 16.0 0 0"
outfile=ah100050030sxi_p0100004b0_rt.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamofile=CALDB onaxisffile=CALDB
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB seed=7 clobber=yes
chatter=2 mode=h logfile=make_arf_ah100050030sxi_p0100004b0.log

aharfgen xrtevtfile=raytrace_ah100050040sxi_p0100004b0_ptsrc_evt.fits
source_ra=278.3889 source_dec=-10.5691 telescop=HITOMI instrume=SXI
emapfile=ah100050040sxi_p0100004b0.expo regmode=SKY
regionfile=../../regions/region_SXI_100050012340.reg sourcetype=POINT
rmffile=ah100050040sxi_p0100004b0_cl.rmf erange="0.5 16.0 0 0"
outfile=ah100050040sxi_p0100004b0_rt.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamofile=CALDB onaxisffile=CALDB
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB seed=7 clobber=yes
chatter=2 mode=h logfile=make_arf_ah100050040sxi_p0100004b0.log

```

MZDYE

```

aharfgen xrtevtfile=raytrace_ah100050010sxi_p0100004b1_ptsrc_evt.fits
source_ra=278.3889 source_dec=-10.5691 telescop=HITOMI instrume=SXI
emapfile=ah100050010sxi_p0100004b1.expo regmode=SKY
regionfile=../../regions/region_SXI_100050012340.reg sourcetype=POINT
rmffile=ah100050010sxi_p0100004b1_cl.rmf erange="0.5 16.0 0 0"

```

```

outfile=ah100050010sxi_p0100004b1_rt.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamofile=CALDB onaxisffile=CALDB
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB seed=7 clobber=yes
chatter=2 mode=h logfile=make_arf_ah100050010sxi_p0100004b1.log

aharfgen xrtevtfile=raytrace_ah100050030sxi_p0100004b1_ptsrc_evt.fits
source_ra=278.3889 source_dec=-10.5691 telescop=HITOMI instrume=SXI
emapfile=ah100050030sxi_p0100004b1.expo regmode=SKY
regionfile=../../regions/region_SXI_100050012340.reg sourcetype=POINT
rmffile=ah100050030sxi_p0100004b1_cl.rmf erange="0.5 16.0 0 0"
outfile=ah100050030sxi_p0100004b1_rt.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamofile=CALDB onaxisffile=CALDB
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB seed=7 clobber=yes
chatter=2 mode=h logfile=make_arf_ah100050030sxi_p0100004b1.log

aharfgen xrtevtfile=raytrace_ah100050040sxi_p0100004b1_ptsrc_evt.fits
source_ra=278.3889 source_dec=-10.5691 telescop=HITOMI instrume=SXI
emapfile=ah100050040sxi_p0100004b1.expo regmode=SKY
regionfile=../../regions/region_SXI_100050012340.reg sourcetype=POINT
rmffile=ah100050040sxi_p0100004b1_cl.rmf erange="0.5 16.0 0 0"
outfile=ah100050040sxi_p0100004b1_rt.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamofile=CALDB onaxisffile=CALDB
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB seed=7 clobber=yes
chatter=2 mode=h logfile=make_arf_ah100050040sxi_p0100004b1.log

```

(4) Correct the BACKSCAL keyword in the SXI spectra for each remaining sequence

Xselect writes a BACKSCAL keyword in the header of extracted spectra to properly scale the background subtraction in XSPEC. However, it only accounts for the fraction of the area covered by the extraction region, not the number of good pixels. Many pixels in SXI data are affected by cosmic-ray echo or light leak and need to be properly excluded from BACKSCAL. The example shown above for 100050020 should be done for all of the ‘Normal’ and ‘MZDYE’ source and background spectra:

Normal mode

```

ah100050010sxi_p0100004b0_cl.pi
ah100050020sxi_p0100004b0_cl.pi
ah100050030sxi_p0100004b0_cl.pi
ah100050040sxi_p0100004b0_cl.pi
ah100050010sxi_p0100004b0_cl_bkg.pi
ah100050020sxi_p0100004b0_cl_bkg.pi
ah100050030sxi_p0100004b0_cl_bkg.pi
ah100050040sxi_p0100004b0_cl_bkg.pi

```

MZDYE

```

ah100050010sxi_p0100004b1_cl.pi
ah100050020sxi_p0100004b1_cl.pi
ah100050030sxi_p0100004b1_cl.pi
ah100050040sxi_p0100004b1_cl.pi

```

(5) Combine SXI spectra and responses

The ftool ‘addascaspec’ should be used to combine the source spectra, background spectra, and responses. Normal mode and MZDYE should be combined separately.

Normal mode

```
addascaspec addascaspec_normal.in ah1000500ALL0sxi_p0100004b0_cl.pi
ah1000500ALL0sxi_p0100004b0_cl.rsp ah1000500ALL0sxi_p0100004b0_cl_bkg.pi
"POISS-0"
```

where the file ‘addascaspec_normal.in’ contains the following four lines (delineated by ‘\’):

```
ah100050010sxi_p0100004b0_cl.pi ah100050020sxi_p0100004b0_cl.pi \
ah100050030sxi_p0100004b0_cl.pi ah100050040sxi_p0100004b0_cl.pi \
ah100050010sxi_p0100004b0_cl_bkg.pi ah100050020sxi_p0100004b0_cl_bkg.pi \
ah100050030sxi_p0100004b0_cl_bkg.pi ah100050040sxi_p0100004b0_cl_bkg.pi \
ah100050010sxi_p0100004b0_rt.arf ah100050020sxi_p0100004b0_rt.arf \
ah100050030sxi_p0100004b0_rt.arf ah100050040sxi_p0100004b0_rt.arf \
ah100050010sxi_p0100004b0_cl.rmf ah100050020sxi_p0100004b0_cl.rmf \
ah100050030sxi_p0100004b0_cl.rmf ah100050040sxi_p0100004b0_cl.rmf
```

This will create a combined source spectrum, combined background spectrum, and a single .rsp file containing both the combined RMF and ARF.

MZDYE

```
addascaspec addascaspec_mzdye.in ah1000500ALL0sxi_p0100004b1_cl.pi
ah1000500ALL0sxi_p0100004b1_cl.rsp ah1000500ALL0sxi_p0100004b1_cl_bkg.pi
"POISS-0"
```

where the file ‘addascaspec_mzdye.in’ contains the following four lines:

```
ah100050010sxi_p0100004b1_cl.pi ah100050020sxi_p0100004b1_cl.pi \
ah100050030sxi_p0100004b1_cl.pi ah100050040sxi_p0100004b1_cl.pi \
ah100050010sxi_p0100004b0_cl_bkg.pi ah100050020sxi_p0100004b0_cl_bkg.pi \
ah100050030sxi_p0100004b0_cl_bkg.pi ah100050040sxi_p0100004b0_cl_bkg.pi \
ah100050010sxi_p0100004b1_rt.arf ah100050020sxi_p0100004b1_rt.arf \
ah100050030sxi_p0100004b1_rt.arf ah100050040sxi_p0100004b1_rt.arf \
ah100050010sxi_p0100004b1_cl.rmf ah100050020sxi_p0100004b1_cl.rmf \
ah100050030sxi_p0100004b1_cl.rmf ah100050040sxi_p0100004b1_cl.rmf
```

This will create a combined source spectrum, combined background spectrum, and a single .rsp file containing both the combined RMF and ARF. Note the ‘Normal’ mode background spectra are used here for the ‘MZDYE’ data because the event threshold in the off-source segments is set very high (about 12 keV) during that mode.

(6) Create an efficiency map (flat field) for each remaining sequence

```
ahexpmap ehkfile=../100050010/auxil/ah100050010.ehk.gz
gtifile=../100050010/sxi/event_cl/ah100050010sxi_p0100004b0_cl.evt.gz
instrume=SXI
badimgfile=../100050010/sxi/event_uf/ah100050010sxi_p0100004b0.bimg.gz
pixgtifile=../100050010/sxi/event_uf/ah100050010sxi_a0100004b0.fpix.gz
outfile=ah100050010sxi_p0100004b0.flat outmaptyp=EFFICIENCY delta=20.0
numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_flat_ah100050010sxi_a0100004b0.log

ahexpmap ehkfile=../100050020/auxil/ah100050020.ehk.gz
gtifile=../100050020/sxi/event_cl/ah100050020sxi_p0100004b0_cl.evt.gz
instrume=SXI
badimgfile=../100050020/sxi/event_uf/ah100050020sxi_p0100004b0.bimg.gz
pixgtifile=../100050020/sxi/event_uf/ah100050020sxi_a0100004b0.fpix.gz
outfile=ah100050020sxi_p0100004b0.flat outmaptyp=EFFICIENCY delta=20.0
numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
```

```

specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_flat_ah100050020sxi_a0100004b0.log

ahexpmap ehkfile=../100050030/auxil/ah100050030.ehk.gz
gtifile=../100050030/sxi/event_cl/ah100050030sxi_p0100004b0_cl.evt.gz
instrume=SXI
badimgfile=../100050030/sxi/event_uf/ah100050030sxi_p0100004b0.bimg.gz
pixgtifile=../100050030/sxi/event_uf/ah100050030sxi_a0100004b0.fpix.gz
outfile=ah100050030sxi_p0100004b0.flat outmappytype=EFFICIENCY delta=20.0
numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contaminfile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_flat_ah100050030sxi_a0100004b0.log

ahexpmap ehkfile=../100050040/auxil/ah100050040.ehk.gz
gtifile=../100050040/sxi/event_cl/ah100050040sxi_p0100004b0_cl.evt.gz
instrume=SXI
badimgfile=../100050040/sxi/event_uf/ah100050040sxi_p0100004b0.bimg.gz
pixgtifile=../100050040/sxi/event_uf/ah100050040sxi_a0100004b0.fpix.gz
outfile=ah100050040sxi_p0100004b0.flat outmappytype=EFFICIENCY delta=20.0
numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contaminfile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_flat_ah100050040sxi_a0100004b0.log

```

MZDYE

```

ahexpmap ehkfile=../100050010/auxil/ah100050010.ehk.gz
gtifile=../100050010/sxi/event_cl/ah100050010sxi_p0100004b1_cl.evt.gz
instrume=SXI
badimgfile=../100050010/sxi/event_uf/ah100050010sxi_p0100004b1.bimg.gz
pixgtifile=../100050010/sxi/event_uf/ah100050010sxi_a0100004b1.fpix.gz
outfile=ah100050010sxi_p0100004b1.flat outmappytype=EFFICIENCY delta=20.0
numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contaminfile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_flat_ah100050010sxi_a0100004b1.log

ahexpmap ehkfile=../100050020/auxil/ah100050020.ehk.gz
gtifile=../100050020/sxi/event_cl/ah100050020sxi_p0100004b1_cl.evt.gz
instrume=SXI
badimgfile=../100050020/sxi/event_uf/ah100050020sxi_p0100004b1.bimg.gz
pixgtifile=../100050020/sxi/event_uf/ah100050020sxi_a0100004b1.fpix.gz
outfile=ah100050020sxi_p0100004b1.flat outmappytype=EFFICIENCY delta=20.0
numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contaminfile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_flat_ah100050020sxi_a0100004b1.log

ahexpmap ehkfile=../100050030/auxil/ah100050030.ehk.gz
gtifile=../100050030/sxi/event_cl/ah100050030sxi_p0100004b1_cl.evt.gz
instrume=SXI
badimgfile=../100050030/sxi/event_uf/ah100050030sxi_p0100004b1.bimg.gz
pixgtifile=../100050030/sxi/event_uf/ah100050030sxi_a0100004b1.fpix.gz
outfile=ah100050030sxi_p0100004b1.flat outmappytype=EFFICIENCY delta=20.0
numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contaminfile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT

```

```

abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_flat_ah100050030sxi_a0100004b1.log

ahexpmap ehkfile=../100050040/auxil/ah100050040.ehk.gz
gtifile=../100050040/sxi/event_cl/ah100050040sxi_p0100004b1_cl.evt.gz
instrume=SXI
badimgfile=../100050040/sxi/event_uf/ah100050040sxi_p0100004b1.bimg.gz
pixgtifile=../100050040/sxi/event_uf/ah100050040sxi_a0100004b1.fpix.gz
outfile=ah100050040sxi_p0100004b1.flat outmapttype=EFFICIENCY delta=20.0
numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_flat_ah100050040sxi_a0100004b1.log

```

SXS

```

cd /full/path/
cd data/products_sxs

```

(1) Generate small and x-large RMF for the combined event file

```

sxsmkrmf infile=ah1000500ALL0sxs_p0px1010_c12.evt
outfile=ah1000500ALL0_sxs_c12_HP_small.rmf resolist=0 regmode=det
regionfile=ah1000500ALL0sxs_region_SXS_det.reg whichrmf=s

sxsmkrmf infile=ah1000500ALL0sxs_p0px1010_c12.evt
outfile=ah1000500ALL0_sxs_c12_HP_xlarge.rmf resolist=0 regmode=det
regionfile=ah1000500ALL0sxs_region_SXS_det.reg whichrmf=x

```

(2) Create or merge the necessary files from each sequence

(a) Merge the ehk files

```

ftmerge
'../100050010/auxil/ah100050010.ehk.gz,../100050020/auxil/ah100050020.ehk.gz,..
/100050030/auxil/ah100050030.ehk.gz,../100050040/auxil/ah100050040.ehk.gz'
ah1000500ALL0.ehk

```

(b) Merge the pixgti file GTIPIXELOFF extensions

```

ftmerge
'../100050010/sxs/event_uf/ah100050010sxs_px1010_exp.gti.gz+2,../100050020/sxs/
event_uf/ah100050020sxs_px1010_exp.gti.gz+2,../100050030/sxs/event_uf/ah1000500
30sxs_px1010_exp.gti.gz+2,../100050040/sxs/event_uf/ah100050040sxs_px1010_exp.g
ti.gz+2' ah1000500ALL0sxs_px1010_exp.gti

```

(3) Create the SXS exposure map for the combined SXS

Note: The exposure maps created with sxsregext are replaced using the parameters delta=20.0, numphi=1 to assure that map includes only a single attitude bin. This accounts for the fact that the attitude is evidently stable relative to the size of the PSF and extraction region. We also account for the lost event gti per pixel here setting pixgtifile=ah1000500ALL0sxs_px1010_exp.gti – this should be done if the lost event gti are not used in the screening (as in the standard pipeline).

```

ahexpmap ehkfile=ah1000500ALL0.ehk gtifile=ah1000500ALL0sxs_p0px1010_c12.evt
instrume=SXS badimgfile=NONE pixgtifile=ah1000500ALL0sxs_px1010_exp.gti
outfile=ah1000500ALL0sxs_p0px1010.expo outmapttype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB

```

```

obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah1000500ALL0sxs_p0px1010.log

```

(4) Create an ARF for the combined SXS

```

aharfgen xrtevtfile=raytrace_ah1000500ALL0sxs_p0px1010.fits source_ra=278.3889
source_dec=-10.5691 telescop=HITOMI instrume=SXS
emapfile=ah1000500ALL0sxs_p0px1010.expo regmode=DET
regionfile=ah1000500ALL0sxs_region_SXS_det.reg sourcetype=POINT
rmffile=ah1000500ALL0_sxs_c12_HP_small.rmf erange="0.5 17.0 0 0"
outfile=ah1000500ALL0sxs_p0px1010_rt.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamofile=CALDB obffile=CALDB fwfile=CALDB
gatevalvefile=CALDB onaxisffile=CALDB onaxiscfle=CALDB mirrorfile=CALDB
obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB
scatterfile=CALDB seed=7 clobber=yes chatter=2 mode=h
logfile=make_arf_ah1000500ALL0sxs_p0px1010.log

```

Note that the `source_ra` and `source_dec` are taken from the region file `region_SXI_100050012340.reg`, i.e. an estimate of the source coordinates based on the SXI image. The region file used is the one in DET coordinates previously created by `sxsregext`.

Spectral Fitting

Notes

The following XSPEC settings are used below.

For fitting;

```

abund wilm
xsect vern
statistic cstat

```

For plotting:

```

setplot rebin 10 20 (HXI, SGD, SXI)
setplot rebin 20 40 (SXS)

```

Note that the spectra and response files co-added for all sequences are used below; however, identical procedures apply to individual sequences.

HXI

(1) Jointly fit the HXII1 and HXII2 deadtime-corrected (no background subtraction) spectra in the 5-20 keV band with power-law model, with absorption fixed at $3.0 \times 10^{22} \text{ cm}^{-2}$ using the RSP files created in the previous section.

```

2 files 2 spectra
Spectrum 1 Spectral Data File: ah1000500ALL0hx1_p0camrec_dtime.pi
Net count rate (cts/s) for Spectrum:1 1.387e+00 +/- 3.842e-03
Assigned to Data Group 1 and Plot Group 1
Noticed Channels: 51-199
Telescope: HITOMI Instrument: HXII1 Channel Type: PI
Exposure Time: 9.394e+04 sec
Using fit statistic: cstat
Using test statistic: chi
Using Response (RMF) File ah1000500ALL0hx1_rt.rsp for Source 1

```

```

Spectral data counts: 130288
Model predicted rate: 1.38691

Spectrum 2 Spectral Data File: ah1000500ALL0hx2_p0camrec_dtime.pi
Net count rate (cts/s) for Spectrum:2 1.397e+00 +/- 3.851e-03
Assigned to Data Group 2 and Plot Group 2
Noticed Channels: 51-199
Telescope: HITOMI Instrument: HXII Channel Type: PI
Exposure Time: 9.42e+04 sec
Using fit statistic: cstat
Using test statistic: chi
Using Response (RMF) File           ah1000500ALL0hx2_rt.rsp for Source 1

Spectral data counts: 131580
Model predicted rate: 1.39682

```

Current model list:

```

=====
Model TBabs<1>*pegpwrlw<2> Source No.: 1 Active/On
Model Model Component Parameter Unit      Value
par comp
                                Data group: 1
 1   1   TBabs      nH      10^22    3.00000   frozen
 2   2   pegpwrlw  PhoIndex        2.08772   +/- 8.20903E-03
 3   2   pegpwrlw  eMin       keV     2.00000   frozen
 4   2   pegpwrlw  eMax       keV     8.00000   frozen
 5   2   pegpwrlw  norm          69.8270   +/- 0.494605
                                Data group: 2
 6   1   TBabs      nH      10^22    3.00000   = p1
 7   2   pegpwrlw  PhoIndex        2.11057   +/- 8.12997E-03
 8   2   pegpwrlw  eMin       keV     2.00000   = p3
 9   2   pegpwrlw  eMax       keV     8.00000   = p4
10   2   pegpwrlw  norm          71.7190   +/- 0.507527
=====
```

Using energies from responses.

```

Fit statistic : C-Statistic =      346.09 using 298 PHA bins and 294 degrees of
freedom.

Test statistic : Chi-Squared =      353.90 using 298 PHA bins.
Reduced chi-squared =      1.2037 for 294 degrees of freedom
Null hypothesis probability = 9.466536e-03
Weighting method: standard

```

(2) Jointly fit the HXII and HXI2 background-subtracted deadtime-corrected spectra in the 5-70 keV band with a broken power-law model, with absorption fixed at $3.0 \times 10^{22} \text{ cm}^{-2}$ using the RSP files created in the previous section.

```

2 files 2 spectra
Spectrum 1 Spectral Data File: ah1000500ALL0hx1_p0camrec_dtime.pi
Net count rate (cts/s) for Spectrum:1 1.420e+00 +/- 4.098e-03 (94.0 % total)
Assigned to Data Group 1 and Plot Group 1
Noticed Channels: 51-699
Telescope: HITOMI Instrument: HXII Channel Type: PI
Exposure Time: 9.394e+04 sec
Using fit statistic: cstat
Using test statistic: chi
Using Background File           ah1000500ALL0hx1_p0camrec_dtime_bkg.pi
Background Exposure Time: 9.394e+04 sec
Using Response (RMF) File       ah1000500ALL0hx1_rt.rsp for Source 1

Spectral data counts: 141916
Model predicted rate: 1.42126

```

Spectrum 2 Spectral Data File: ah1000500ALL0hx2_p0camrec_dtime.pi

```

Net count rate (cts/s) for Spectrum:2 1.448e+00 +/- 4.097e-03 (94.9 % total)
Assigned to Data Group 2 and Plot Group 2
Noticed Channels: 51-699
Telescope: HITOMI Instrument: HXI2 Channel Type: PI
Exposure Time: 9.42e+04 sec
Using fit statistic: cstat
Using test statistic: chi
Using Background File ah1000500ALL0hx2_p0camrec_dtime_bkg.pi
Background Exposure Time: 9.42e+04 sec
Using Response (RMF) File ah1000500ALL0hx2_rt.rsp for Source 1

Spectral data counts: 143640
Model predicted rate: 1.44614

```

Current model list:

```

=====
Model TBabs<1>*pegpwrlw<2> Source No.: 1 Active/On
Model Model Component Parameter Unit Value
par comp
                                Data group: 1
1    1    TBabs      nH          10^22     3.00000   frozen
2    2    pegpwrlw  PhoIndex    2.12803   +/- 6.93682E-03
3    2    pegpwrlw  eMin        keV       2.00000   frozen
4    2    pegpwrlw  eMax        keV       8.00000   frozen
5    2    pegpwrlw  norm        69.0443   +/- 0.453106
                                Data group: 2
6    1    TBabs      nH          10^22     3.00000   = p1
7    2    pegpwrlw  PhoIndex    2.13395   +/- 6.73490E-03
8    2    pegpwrlw  eMin        keV       2.00000   = p3
9    2    pegpwrlw  eMax        keV       8.00000   = p4
10   2    pegpwrlw  norm        70.5407   +/- 0.454535
=====
```

Using energies from responses.

Fit statistic : C-Statistic = 1493.19 using 1298 PHA bins and 1294 degrees of freedom.

Test statistic : Chi-Squared = 1528.29 using 1298 PHA bins.
Reduced chi-squared = 1.18106 for 1294 degrees of freedom
Null hypothesis probability = 6.310093e-06
Weighting method: standard

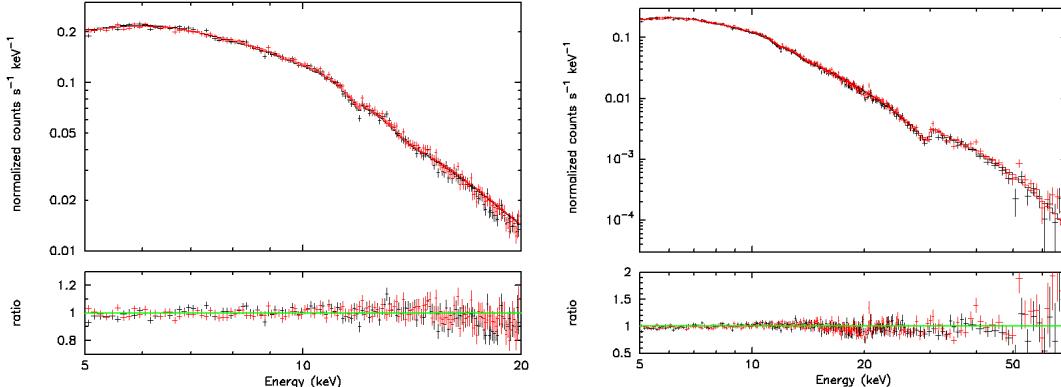


Figure 12: Joint fits to HXI1 (black) and HXI2 (red) spectra for combined G21.5-0.9 sequences 100050010, 100050020, 100050030, 100050040 – without (left) and with (right) local background subtraction. The 2-8 keV unabsorbed fluxes are $\sim 6.9\text{-}7.2 \times 10^{-11}$ erg cm $^{-2}$ s $^{-1}$ in the best-fit models – lower than in Nynka et al. 2014 (ApJ, 789, 72) and Tsujimoto et al. 2011 (A&A, 525, 25).

SGD

(1) Compare the deadtime-corrected and the deadtime-uncorrected SGD1 spectra (summed over all relevant sequences and all Compton cameras) with the estimated CALDB NXB spectrum
\$CALDB/data/hitomi/sgd/cpf/background/ah_sgd_nxb_20140101v001.pha.

```
3 files 3 spectra
Spectrum 1 Spectral Data File: ah_sgd_nxb_20140101v001.pha
Net count rate (cts/s) for Spectrum:1 7.661e-01 +/- 1.153e-03
Assigned to Data Group 1 and Plot Group 1
Noticed Channels: 42-2048
Telescope: HITOMI Instrument: SGD Channel Type: PI
Exposure Time: 5.763e+05 sec
Using fit statistic: cstat
Using test statistic: chi
Using Response (RMF) File           ah1000500ALL0sg1_ccALL_dtime_wtd.rsp for
Source 1

Spectral data counts: 441486
Model predicted rate: 0.0

Spectrum 2 Spectral Data File: ah1000500ALL0sg1_p0ccALLrec_cl.pi
Net count rate (cts/s) for Spectrum:2 1.059e+00 +/- 3.885e-03
Assigned to Data Group 2 and Plot Group 2
Noticed Channels: 42-2048
Telescope: HITOMI Instrument: SGD1 Channel Type: PI
Exposure Time: 7.019e+04 sec
Using fit statistic: cstat
Using test statistic: chi
Using Response (RMF) File           ah1000500ALL0sg1_ccALL_dtime_wtd.rsp for
Source 1

Spectral data counts: 74359
Model predicted rate: 0.0

Spectrum 3 Spectral Data File: ah1000500ALL0sg1_p0ccALLrec_dtime.pi
Net count rate (cts/s) for Spectrum:3 1.730e+00 +/- 6.345e-03
Assigned to Data Group 3 and Plot Group 3
Noticed Channels: 42-2048
Telescope: HITOMI Instrument: SGD1 Channel Type: PI
Exposure Time: 4.297e+04 sec
Using fit statistic: cstat
Using test statistic: chi
Using Response (RMF) File           ah1000500ALL0sg1_ccALL_dtime_wtd.rsp for
Source 1

Spectral data counts: 74359
Model predicted rate: 0.0
```

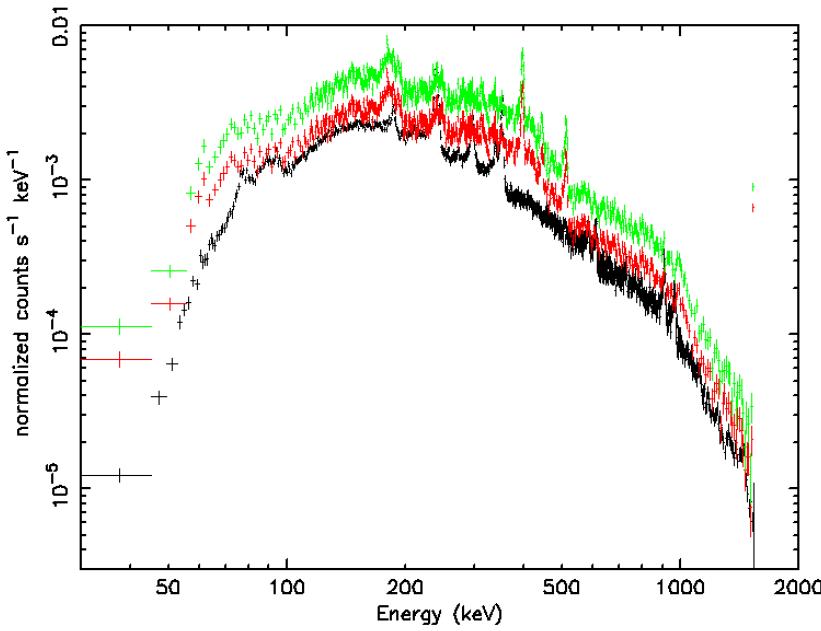


Figure 13: Comparison of NXB file in CALDB (black) with deadtime-corrected (green) and deadtime-uncorrected (red) spectra from combined G21.5-0.9 sequences 100050010, 100050020, 100050030, 100050040 .

SXI

(1) Jointly fit the SXI normal and MZDYE background-subtracted spectra in the 0.8-12 keV band with a power-law model, with absorption fixed at $3.0 \times 10^{22} \text{ cm}^{-2}$ using the ARF files created in the previous section:

```

2 files 2 spectra
Spectrum 1 Spectral Data File: ah100050012340sxi_p0100004b0_cl.pi
Net count rate (cts/s) for Spectrum:1 3.012e+00 +/- 7.682e-03 (98.8 % total)
Assigned to Data Group 1 and Plot Group 1
Noticed Channels: 135-1999
Telescope: HITOMI Instrument: SXI Channel Type: PI
Exposure Time: 5.171e+04 sec
Using fit statistic: cstat
Using test statistic: chi
Using Background File           ah100050012340sxi_p0100004b0_cl_bkg.pi
Background Exposure Time: 5.171e+04 sec
Using Response (RMF) File       ah100050012340sxi_p0100004b0_cl.rsp for
Source 1

Spectral data counts: 157715
Model predicted rate: 3.01344

Spectrum 2 Spectral Data File: ah100050012340sxi_p0100004b1_cl.pi
Net count rate (cts/s) for Spectrum:2 1.580e+00 +/- 7.181e-03 (99.3 % total)
Assigned to Data Group 2 and Plot Group 2
Noticed Channels: 135-1999
Telescope: HITOMI Instrument: SXI Channel Type: PI
Exposure Time: 3.086e+04 sec
Using fit statistic: cstat
Using test statistic: chi
Using Background File           ah100050012340sxi_p0100004b1_cl_bkg.pi
Background Exposure Time: 5.171e+04 sec
Using Response (RMF) File       ah100050012340sxi_p0100004b1_cl.rsp for
Source 1

```

Spectral data counts: 49097
 Model predicted rate: 1.58092

Current model list:

=====						
Model		Model	Component	Parameter	Unit	Value
par	comp					
Data group: 1						
1	1	TBabs	nH	10^{22}		3.00000
2	2	pegpwrlw	PhoIndex			1.86843
3	2	pegpwrlw	eMin	keV		2.00000
4	2	pegpwrlw	eMax	keV		8.00000
5	2	pegpwrlw	norm			56.9552
Data group: 2						
6	1	TBabs	nH	10^{22}		3.00000
7	2	pegpwrlw	PhoIndex			1.83503
8	2	pegpwrlw	eMin	keV		2.00000
9	2	pegpwrlw	eMax	keV		8.00000
10	2	pegpwrlw	norm			54.9935

Using energies from responses.

Fit statistic : C-Statistic = 4478.74 using 3730 PHA bins and 3726 degrees of freedom.

Test statistic : Chi-Squared = 404834.5 using 3730 PHA bins.
 Reduced chi-squared = 108.6512 for 3726 degrees of freedom
 Null hypothesis probability = 0.000000e+00
 Weighting method: standard

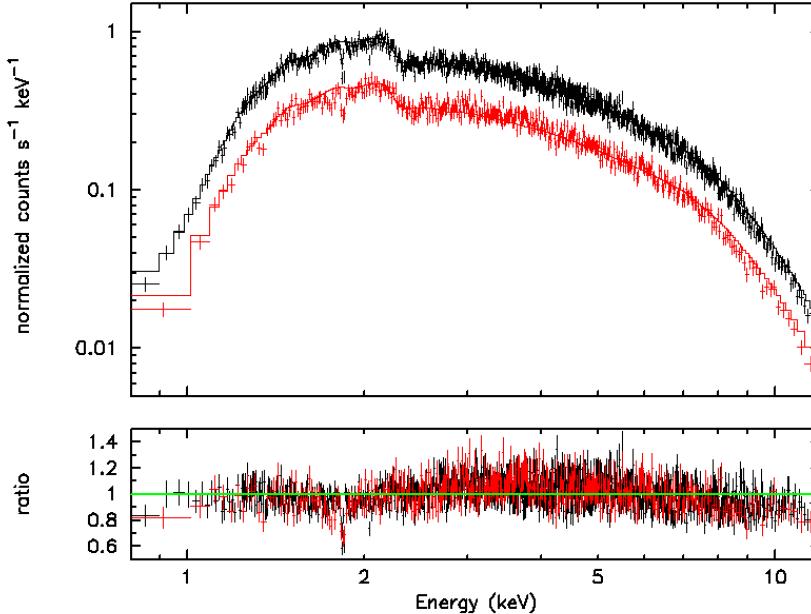


Figure 14: Joint fits to SXI Normal mode (black) and MZDYE (red) spectra for combined G21.5-0.9 sequences 100050010, 100050020, 100050030, 100050040 using the RMF and ARF files derived in the previous section. The 2-8 keV unabsorbed fluxes are $5.7 (5.5) \times 10^{-11} \text{ erg cm}^{-2} \text{ s}^{-1}$ in the best-fit models to the normal (MZDYE) spectra.

SXS

(1) Fit the SXS spectrum in the 2-12 keV band with a power-law model, with absorption fixed at $3.0 \times 10^{22} \text{ cm}^{-2}$ using the small RMF file, and the ARF file created in the previous section

```
1 file 1 spectrum
Spectrum 1  Spectral Data File: ah1000500ALL0sxs_p0px1010_c12_HP.pi
Net count rate (cts/s) for Spectrum:1  7.639e-01 +/- 2.208e-03
Assigned to Data Group 1 and Plot Group 1
Noticed Channels: 4001-23999
Telescope: HITOMI Instrument: SXS Channel Type: PI
Exposure Time: 1.568e+05 sec
Using fit statistic: cstat
Using test statistic: chi
Using Response (RMF) File           ah1000500ALL0_sxs_c12_HP_small.rmf for
Source 1
Using Auxiliary Response (ARF) File ah1000500ALL0sxs_p0px1010_rt.arf

Spectral data counts: 119740
Model predicted rate: 0.763873
```

Current model list:

```
=====
Model TBabs<1>*pegpwrlw<2> Source No.: 1 Active/On
Model Model Component Parameter Unit      Value
par comp
 1   1   TBabs      nH        10^22    3.00000   frozen
 2   2   pegpwrlw  PhoIndex      2.00905   +/- 8.03883E-03
 3   2   pegpwrlw  eMin       keV      2.00000   frozen
 4   2   pegpwrlw  eMax       keV      8.00000   frozen
 5   2   pegpwrlw  norm        62.3415  +/- 0.218544
```

Using energies from responses.

```
Fit statistic : C-Statistic =      21330.63 using 19999 PHA bins and 19997
degrees of freedom.

Test statistic : Chi-Squared =      23625.72 using 19999 PHA bins.
Reduced chi-squared =      1.181463 for 19997 degrees of freedom
Null hypothesis probability =  2.934982e-66

***Warning: Chi-square may not be valid due to bins with zero variance
in spectrum number(s): 1
```

Weighting method: standard

(2) Fit the SXS spectrum in the 0.6-12 keV band with a power-law model, with absorption fixed at $3.0 \times 10^{22} \text{ cm}^{-2}$ using the x-large RMF file, and the ARF file created in the previous section

```
1 file 1 spectrum
Spectrum 1  Spectral Data File: ah1000500ALL0sxs_p0px1010_c12_HP.pi
Net count rate (cts/s) for Spectrum:1  7.710e-01 +/- 2.218e-03
Assigned to Data Group 1 and Plot Group 1
Noticed Channels: 1201-23999
Telescope: HITOMI Instrument: SXS Channel Type: PI
Exposure Time: 1.568e+05 sec
Using fit statistic: cstat
Using test statistic: chi
Using Response (RMF) File           ah1000500ALL0_sxs_c12_HP_xlarge.rmf for
Source 1
```

```
Using Auxiliary Response (ARF) File ah1000500ALL0sxs_p0px1010_rt.arf
```

```
Spectral data counts: 120857  
Model predicted rate: 0.770999
```

```
Current model list:
```

```
=====
Model TBabs<1>*pegpwrlw<2> Source No.: 1 Active/On
Model Model Component Parameter Unit Value
par comp
 1   1   TBabs      nH        10^22    3.00000    frozen
 2   2   pegpwrlw  PhoIndex   1.97994  +/- 8.12936E-03
 3   2   pegpwrlw  eMin      keV      2.00000    frozen
 4   2   pegpwrlw  eMax      keV      8.00000    frozen
 5   2   pegpwrlw  norm      62.4193  +/- 0.220020
```

```
Using energies from responses.
```

```
Fit statistic : C-Statistic = 24108.77 using 22799 PHA bins and 22797
degrees of freedom.
```

```
Test statistic : Chi-Squared = 24760.43 using 22799 PHA bins.
Reduced chi-squared = 1.086127 for 22797 degrees of freedom
Null hypothesis probability = 1.828805e-19
```

```
***Warning: Chi-square may not be valid due to bins with zero variance
in spectrum number(s): 1
```

```
Weighting method: standard
```

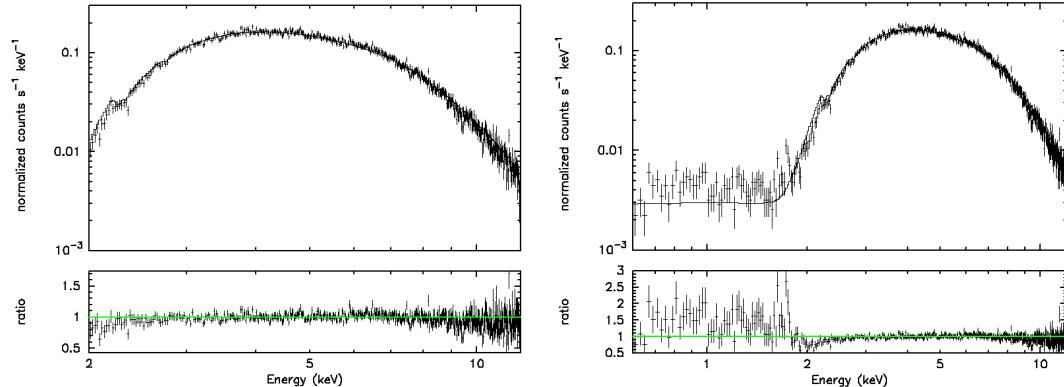


Figure 15: Fits to SXS spectra for combined G21.5-0.9 sequences 100050010, 100050020, 100050030, 100050040 sequence in the 2-12 keV band using the amall-sized RMF file (left) and in the 0.6-12 keV band using the extra-large RMF file (right). The 2-8 keV unabsorbed fluxes are $\sim 6.2 \times 10^{-11} \text{ erg cm}^{-2} \text{ s}^{-1}$ in the best-fit models.

JOINT FITS

(1) Jointly fit the background subtracted HXI1, HXI2 spectra in the 5-70 keV band, the background subtracted SXI normal spectrum in the 0.8-12 keV band, and the SXS spectrum in the 0.6-12 keV band with a power-law model with index tied among detectors, and with absorption fixed at $3.0 \times 10^{22} \text{ cm}^{-2}$. The xlarge-sized matrix is used for the SXS.

```
4 files 4 spectra
Spectrum 1  Spectral Data File: ah1000500ALL0sxs_p0px1010_c12_HP.pi
Net count rate (cts/s) for Spectrum:1 7.710e-01 +/- 2.218e-03
Assigned to Data Group 1 and Plot Group 1
Noticed Channels: 1201-23999
```

```

Telescope: HITOMI Instrument: SXS Channel Type: PI
Exposure Time: 1.568e+05 sec
Using fit statistic: cstat
Using test statistic: chi
Using Response (RMF) File           ah1000500ALL0_sxs_c12_HP_xlarge.rmf for
Source 1
Using Auxiliary Response (ARF) File ah1000500ALL0sxs_p0px1010_rt.arf

Spectral data counts: 120857
Model predicted rate: 0.771027

Spectrum 2 Spectral Data File: ah100050012340sxi_p0100004b0_cl.pi
Net count rate (cts/s) for Spectrum:2 3.012e+00 +/- 7.682e-03 (98.8 % total)
Assigned to Data Group 2 and Plot Group 2
Noticed Channels: 135-1999
Telescope: HITOMI Instrument: SXI Channel Type: PI
Exposure Time: 5.171e+04 sec
Using fit statistic: cstat
Using test statistic: chi
Using Background File           ah100050012340sxi_p0100004b0_cl_bkg.pi
Background Exposure Time: 5.171e+04 sec
Using Response (RMF) File           ah100050012340sxi_p0100004b0_cl.rsp for
Source 1

Spectral data counts: 157715
Model predicted rate: 3.01182

Spectrum 3 Spectral Data File: ah1000500ALL0hx1_p0camrec_dtime.pi
Net count rate (cts/s) for Spectrum:3 1.420e+00 +/- 4.098e-03 (94.0 % total)
Assigned to Data Group 3 and Plot Group 3
Noticed Channels: 51-699
Telescope: HITOMI Instrument: HXII Channel Type: PI
Exposure Time: 9.394e+04 sec
Using fit statistic: cstat
Using test statistic: chi
Using Background File           ah1000500ALL0hx1_p0camrec_dtime_bkg.pi
Background Exposure Time: 9.394e+04 sec
Using Response (RMF) File           ah1000500ALL0hx1_rt.rsp for Source 1

Spectral data counts: 141916
Model predicted rate: 1.42464

Spectrum 4 Spectral Data File: ah1000500ALL0hx2_p0camrec_dtime.pi
Net count rate (cts/s) for Spectrum:4 1.448e+00 +/- 4.097e-03 (94.9 % total)
Assigned to Data Group 4 and Plot Group 4
Noticed Channels: 51-699
Telescope: HITOMI Instrument: HXI2 Channel Type: PI
Exposure Time: 9.42e+04 sec
Using fit statistic: cstat
Using test statistic: chi
Using Background File           ah1000500ALL0hx2_p0camrec_dtime_bkg.pi
Background Exposure Time: 9.42e+04 sec
Using Response (RMF) File           ah1000500ALL0hx2_rt.rsp for Source 1

Spectral data counts: 143640
Model predicted rate: 1.44967

```

Current model list:

```
=====
Model TBabs<1>*pegpwrlw<2> Source No.: 1 Active/On
Model Model Component Parameter Unit      Value
par comp
Data group: 1
```

1	1	TBabs	nH	10^22	3.00000	frozen
2	2	pegpwrlw	PhoIndex		1.99943	+/- 3.12979E-03
3	2	pegpwrlw	eMin	keV	2.00000	frozen
4	2	pegpwrlw	eMax	keV	8.00000	frozen
5	2	pegpwrlw	norm		62.7177	+/- 0.186840
Data group: 2						
6	1	TBabs	nH	10^22	3.00000	frozen
7	2	pegpwrlw	PhoIndex		1.99943	= p2
8	2	pegpwrlw	eMin	keV	2.00000	= p3
9	2	pegpwrlw	eMax	keV	8.00000	= p4
10	2	pegpwrlw	norm		55.7007	+/- 0.144175
Data group: 3						
11	1	TBabs	nH	10^22	3.00000	frozen
12	2	pegpwrlw	PhoIndex		1.99943	= p2
13	2	pegpwrlw	eMin	keV	2.00000	= p3
14	2	pegpwrlw	eMax	keV	8.00000	= p4
15	2	pegpwrlw	norm		61.8309	+/- 0.239799
Data group: 4						
16	1	TBabs	nH	10^22	3.00000	frozen
17	2	pegpwrlw	PhoIndex		1.99943	= p2
18	2	pegpwrlw	eMin	keV	2.00000	= p3
19	2	pegpwrlw	eMax	keV	8.00000	= p4
20	2	pegpwrlw	norm		62.7726	+/- 0.242495

Using energies from responses.

Fit statistic : C-Statistic = 29437.10 using 25962 PHA bins and 25957 degrees of freedom.

Test statistic : Chi-Squared = 30469.26 using 25962 PHA bins.
 Reduced chi-squared = 1.173836 for 25957 degrees of freedom
 Null hypothesis probability = 7.548562e-79

***Warning: Chi-square may not be valid due to bins with zero variance in spectrum number(s): 1

Weighting method: standard

(2) Same as (1), but with SXS, SXI, and HXI12 power-law index untied.

```
4 files 4 spectra
Spectrum 1 Spectral Data File: ah1000500ALL0sxs_p0px1010_c12_HP.pi.gz
Net count rate (cts/s) for Spectrum:1 7.709e-01 +/- 2.218e-03
Assigned to Data Group 1 and Plot Group 1
Noticed Channels: 1201-23999
Telescope: HITOMI Instrument: SXS Channel Type: PI
Exposure Time: 1.568e+05 sec
Using fit statistic: cstat
Using test statistic: chi
Using Response (RMF) File ah1000500ALL0_sxs_c12_HP_xlarge1.rmf for
Source 1
Using Auxiliary Response (ARF) File ah1000500ALL0sxs_p0px1010_rt.arf.gz

Spectral data counts: 120847
Model predicted rate: 0.770937

Spectrum 2 Spectral Data File: ah1000500ALL0sxi_p0100004b0_cl.pi.gz
Net count rate (cts/s) for Spectrum:2 3.016e+00 +/- 7.678e-03 (99.0 % total)
Assigned to Data Group 2 and Plot Group 2
Noticed Channels: 135-1999
Telescope: HITOMI Instrument: SXI Channel Type: PI
Exposure Time: 5.171e+04 sec
Using fit statistic: cstat
```

```

Using test statistic: chi
Using Background File ah1000500ALL0sxi_p0100004b0_c1_bkg.pi.gz
Background Exposure Time: 5.171e+04 sec
Using Response (RMF) File ah1000500ALL0sxi_p0100004b0_c1.rmf.gz for
Source 1
Using Auxiliary Response (ARF) File ah1000500ALL0sxi_p0100004b0_rt.arf.gz

Spectral data counts: 157603
Model predicted rate: 3.01656

Spectrum 3 Spectral Data File: ah1000500ALL0hx1_p0camrec_dtime.pi.gz
Net count rate (cts/s) for Spectrum:3 1.417e+00 +/- 4.097e-03 (93.9 % total)
Assigned to Data Group 3 and Plot Group 3
Noticed Channels: 51-699
Telescope: HITOMI Instrument: HXII Channel Type: PI
Exposure Time: 9.394e+04 sec
Using fit statistic: cstat
Using test statistic: chi
Using Background File ah1000500ALL0hx1_p0camrec_dtime_bkg.pi.gz
Background Exposure Time: 9.394e+04 sec
Using Response (RMF) File ah1000500ALL0hx1_rt.rsp.gz for Source 1

Spectral data counts: 141733
Model predicted rate: 1.41733

Spectrum 4 Spectral Data File: ah1000500ALL0hx2_p0camrec_dtime.pi.gz
Net count rate (cts/s) for Spectrum:4 1.439e+00 +/- 4.108e-03 (94.3 % total)
Assigned to Data Group 4 and Plot Group 4
Noticed Channels: 51-699
Telescope: HITOMI Instrument: HXII Channel Type: PI
Exposure Time: 9.419e+04 sec
Using fit statistic: cstat
Using test statistic: chi
Using Background File ah1000500ALL0hx2_p0camrec_dtime_bkg.pi.gz
Background Exposure Time: 9.419e+04 sec
Using Response (RMF) File ah1000500ALL0hx2_rt.rsp.gz for Source 1

Spectral data counts: 143721
Model predicted rate: 1.44046

```

Current model list:

```
=====
Model TBabs<1>*pegpwrlw<2> Source No.: 1 Active/On
Model Model Component Parameter Unit Value
par comp
Data group: 1
 1   1   TBabs      nH        10^22    3.00000  frozen
 2   2   pegpwrlw  PhoIndex      1.98176  +/- 8.12821E-03
 3   2   pegpwrlw  eMin       keV     2.00000  frozen
 4   2   pegpwrlw  eMax       keV     8.00000  frozen
 5   2   pegpwrlw  norm        61.8754  +/- 0.216424
Data group: 2
 6   1   TBabs      nH        10^22    3.00000  frozen
 7   2   pegpwrlw  PhoIndex      1.86690  +/- 4.85406E-03
 8   2   pegpwrlw  eMin       keV     2.00000  = p3
 9   2   pegpwrlw  eMax       keV     8.00000  = p4
10   2   pegpwrlw  norm        56.8485  +/- 0.151254
Data group: 3
11   1   TBabs      nH        10^22    3.00000  frozen
12   2   pegpwrlw  PhoIndex      2.13768  +/- 4.87943E-03
13   2   pegpwrlw  eMin       keV     2.00000  = p3
14   2   pegpwrlw  eMax       keV     8.00000  = p4
15   2   pegpwrlw  norm        69.5282  +/- 0.351162
```

```

Data group: 4
16   1   TBabs      nH          10^22      3.00000      frozen
17   2   pegpwrlw   PhoIndex        2.13768      = p12
18   2   pegpwrlw   eMin         keV       2.00000      = p3
19   2   pegpwrlw   eMax         keV       8.00000      = p4
20   2   pegpwrlw   norm           71.8300      +/- 0.362723

```

Using energies from responses.

Fit statistic : C-Statistic = 28115.07 using 25962 PHA bins and 25955 degrees of freedom.

Test statistic : Chi-Squared = 29396.43 using 25962 PHA bins.
 Reduced chi-squared = 1.132592 for 25955 degrees of freedom
 Null hypothesis probability = 7.281919e-48

***Warning: Chi-square may not be valid due to bins with zero variance in spectrum number(s): 1

Weighting method: standard

(3) Same as (2), but with SXS, SXI, and HXI12 NH free and untied

4 files 4 spectra

Spectral Data File: ah100050012340sxi_p0100004b0_cl.pi Spectrum 2
 Net count rate (cts/s) for Spectrum:2 3.012e+00 +/- 7.682e-03 (98.8 % total)
 Assigned to Data Group 2 and Plot Group 2
 Noticed Channels: 135-1999
 Telescope: HITOMI Instrument: SXI Channel Type: PI
 Exposure Time: 5.171e+04 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Background File ah100050012340sxi_p0100004b0_cl_bkg.pi
 Background Exposure Time: 5.171e+04 sec
 Using Response (RMF) File ah100050012340sxi_p0100004b0_cl.rsp for Source 1

Spectral Data File: ah1000500ALL0hx1_p0camrec_dtime.pi Spectrum 3
 Net count rate (cts/s) for Spectrum:3 1.420e+00 +/- 4.098e-03 (94.0 % total)
 Assigned to Data Group 3 and Plot Group 3
 Noticed Channels: 51-699
 Telescope: HITOMI Instrument: HXI1 Channel Type: PI
 Exposure Time: 9.394e+04 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Background File ah1000500ALL0hx1_p0camrec_dtime_bkg.pi
 Background Exposure Time: 9.394e+04 sec
 Using Response (RMF) File ah1000500ALL0hx1_rt.rsp for Source 1

Spectral Data File: ah1000500ALL0hx2_p0camrec_dtime.pi Spectrum 4
 Net count rate (cts/s) for Spectrum:4 1.448e+00 +/- 4.097e-03 (94.9 % total)
 Assigned to Data Group 4 and Plot Group 4
 Noticed Channels: 51-699
 Telescope: HITOMI Instrument: HXI2 Channel Type: PI
 Exposure Time: 9.42e+04 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Background File ah1000500ALL0hx2_p0camrec_dtime_bkg.pi
 Background Exposure Time: 9.42e+04 sec
 Using Response (RMF) File ah1000500ALL0hx2_rt.rsp for Source 1

Spectral Data File: ah1000500ALL0sxs_p0px1010_cl2_HP.pi Spectrum 1
 Net count rate (cts/s) for Spectrum:1 7.710e-01 +/- 2.218e-03
 Assigned to Data Group 1 and Plot Group 1
 Noticed Channels: 1201-23999
 Telescope: HITOMI Instrument: SXS Channel Type: PI
 Exposure Time: 1.568e+05 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Response (RMF) File ah1000500ALL0_sxs_cl2_HP_xlarge.rmf for
 Source 1
 Using Auxiliary Response (ARF) File ah1000500ALL0sxs_p0px1010_rt.arf

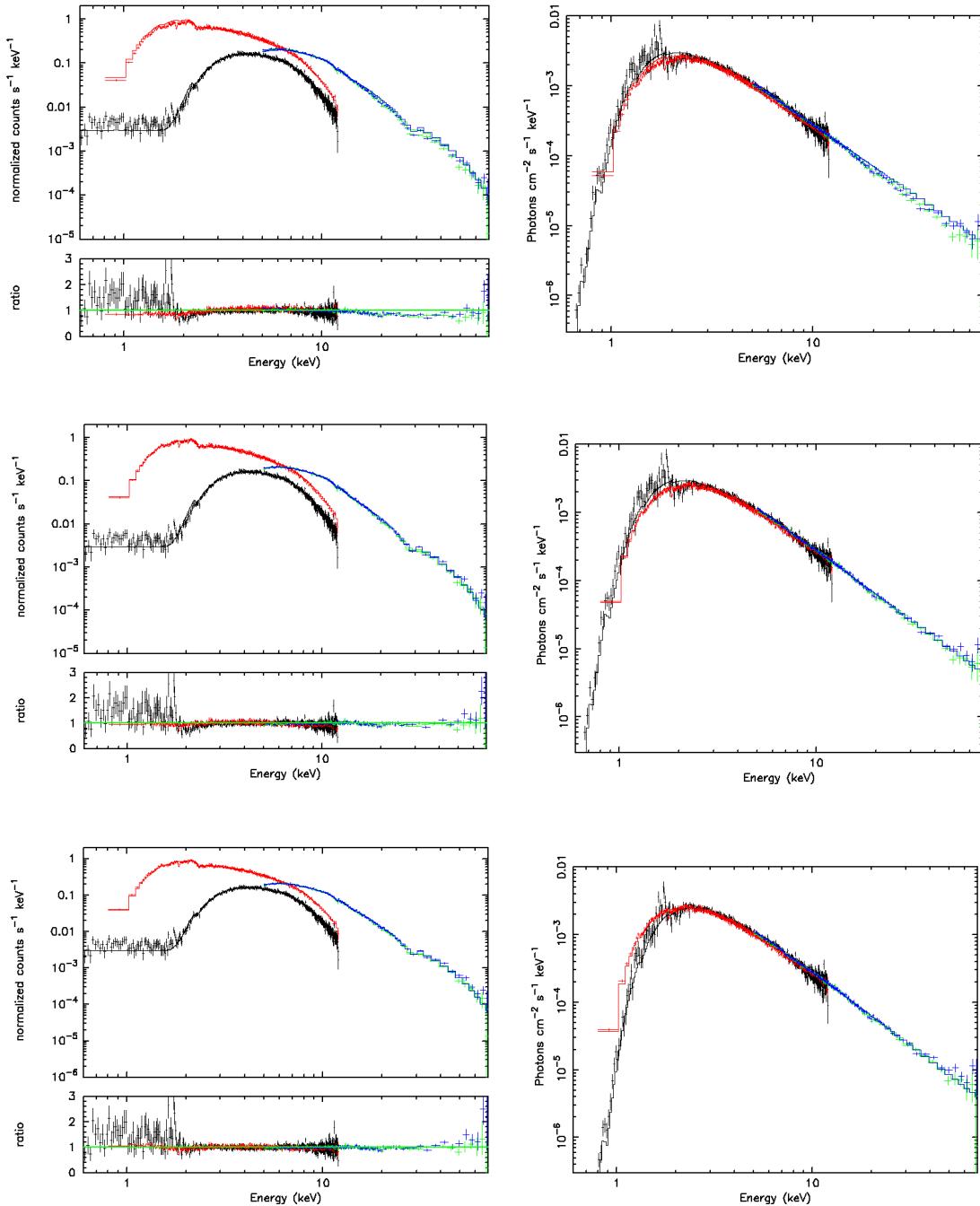


Figure 16: LEFT: Joint fits to HXI1 5-70 keV (green), HXI2 5-70 keV (blue), SXI 0.8-12 keV (red) and SXS 0.6-12 keV (black) spectra for combined G21.5-0.9 sequences 100050010, 100050020, 100050030, 100050040 -- best-fit absorbed power-law model (N_H fixed at $3.0 \times 10^{22} \text{ cm}^{-2}$) with data-to-model ratio (left). RIGHT: Unfolded spectrum. Local background is subtracted for the HXI and SXI, and the xlarge SXS rmf is used. Power-law index is tied (untied) in upper (middle) plots, power-law index and absorption are untied in the bottom plots.

Perseus Cluster

Data description

Table 4a	100040010	100040020
GEN-HK	ah100040010gen_a0.hk1.gz	ah100040020gen_a0.hk1.gz
TIM	ah100040010.tim.gz	ah100040020.tim.gz
ATTITUDE	ah100040010.att.gz	ah100040020.att.gz
ORBIT	ah100040010.orb.gz	ah100040020.orb.gz
OBSGTI	ah100040010_gen.gti.gz	ah100040020_gen.gti.gz
MKF	ah100040010.mkf.gz	ah100040020.mkf.gz
EHK	ah100040010.ehk.gz	ah100040020.ehk.gz
EHK2	ah100040010.ehk2.gz	ah100040020.ehk2.gz
SXS HK	ah100040010sxs_a0.hk1.gz	ah100040020sxs_a0.hk1.gz
SXS ADR	ahsxs_adr.gti.gz	ahsxs_adr.gti.gz
SXS AC EVT	ah100040010sxs_a0ac_uf.evt.gz	ah100040020sxs_a0ac_uf.evt.gz
SXS PIX12 GAIN	ah100040010sxs_010_px12.ghf.gz	ah100040020sxs_010_px12.ghf.gz
SXS PIX12 EVT	ah100040010sxs_a0px12010_uf.evt.gz	ah100040020sxs_a0px12010_uf.evt.gz
SXS EL GTI	ah100040010sxs_el.gti.gz	ah100040020sxs_el.gti.gz
SXS TEL	ah100040010sxs_tel.gti.gz	ah100040020sxs_tel.gti.gz
SXS PIX GTI	ah100040010sxs_p0px1010.gti.gz	ah100040020sxs_p0px1010.gti.gz
SXS PIX EXP	ah100040010sxs_p0px1010_exp.gti.gz	ah100040020sxs_p0px1010_exp.gti.gz
SXS PIX UF	ah100040010sxs_p0px1010_uf.evt.gz	ah100040020sxs_p0px1010_uf.evt.gz
SXS PIX CL	ah100040010sxs_p0px1010_cl.evt.gz	ah100040020sxs_p0px1010_cl.evt.gz

Table 4b	100040030	100040040
GEN-HK	ah100040030gen_a0.hk1.gz	ah100040040gen_a0.hk1.gz
TIM	ah100040030.tim.gz	ah100040040.tim.gz
ATTITUDE	ah100040030.att.gz	ah100040040.att.gz
ORBIT	ah100040030.orb.gz	ah100040040.orb.gz
OBSGTI	ah100040030_gen.gti.gz	ah100040040_gen.gti.gz
MKF	ah100040030.mkf.gz	ah100040040.mkf.gz
EHK	ah100040030.ehk.gz	ah100040040.ehk.gz
EHK2	ah100040030.ehk2.gz	ah100040040.ehk2.gz
SXS HK	ah100040030sxs_a0.hk1.gz	ah100040040sxs_a0.hk1.gz
SXS ADR	ahsxs_adr.gti.gz	ahsxs_adr.gti.gz
SXS AC EVT	ah100040030sxs_a0ac_uf.evt.gz	ah100040040sxs_a0ac_uf.evt.gz
SXS PIX12 GAIN	ah100040030sxs_010_px12.ghf.gz	ah100040040sxs_010_px12.ghf.gz
SXS PIX12 EVT	ah100040030sxs_a0px12010_uf.evt.gz	ah100040040sxs_a0px12010_uf.evt.gz
SXS EL GTI	ah100040030sxs_el.gti.gz	ah100040040sxs_el.gti.gz
SXS TEL	ah100040030sxs_tel.gti.gz	ah100040040sxs_tel.gti.gz
SXS PIX GTI	ah100040030sxs_p0px1010.gti.gz	ah100040040sxs_p0px1010.gti.gz
SXS PIX EXP	ah100040030sxs_p0px1010_exp.gti.gz	ah100040040sxs_p0px1010_exp.gti.gz
SXS PIX UF	ah100040030sxs_p0px1010_uf.evt.gz	ah100040040sxs_p0px1010_uf.evt.gz
SXS PIX CL	ah100040030sxs_p0px1010_cl.evt.gz	ah100040040sxs_p0px1010_cl.evt.gz

Table 4c	100040050	100040060
GEN-HK	ah100040050gen_a0.hk1.gz	ah100040060gen_a0.hk1.gz
TIM	ah100040050.tim.gz	ah100040060.tim.gz
ATTITUDE	ah100040050.att.gz	ah100040060.att.gz
ORBIT	ah100040050.orb.gz	ah100040060.orb.gz
OBSGTI	ah100040050_gen.gti.gz	ah100040060_gen.gti.gz
MKF	ah100040050.mkf.gz	ah100040060.mkf.gz

EHK	ah100040050.ehk.gz	ah100040060.ehk.gz
EHK2	ah100040050.ehk2.gz	ah100040060.ehk2.gz
SXS HK	ah100040050sxs_a0.hk1.gz	ah100040060sxs_a0.hk1.gz
SXS ADR	ahsxs_adr.gti.gz	ahsxs_adr.gti.gz
SXS AC EVT	ah100040050sxs_a0ac_uf.evt.gz	ah100040060sxs_a0ac_uf.evt.gz
SXS PIX12 GAIN	ah100040050sxs_010_px12.ghf.gz	ah100040060sxs_010_px12.ghf.gz
SXS PIX12 EVT	ah100040050sxs_a0px12010_uf.evt.gz	ah100040060sxs_a0px12010_uf.evt.gz
SXS EL GTI	ah100040050sxs_el.gti.gz	ah100040060sxs_el.gti.gz
SXS TEL	ah100040050sxs_tel.gti.gz	ah100040060sxs_tel.gti.gz
SXS PIX GTI	ah100040050sxs_p0px1010.gti.gz	ah100040060sxs_p0px1010.gti.gz
SXS PIX EXP	ah100040050sxs_p0px1010_exp.gti.gz	ah100040060sxs_p0px1010_exp.gti.gz
SXS PIX UF	ah100040050sxs_p0px1010_uf.evt.gz	ah100040060sxs_p0px1010_uf.evt.gz
SXS PIX CL	ah100040050sxs_p0px1010_cl.evt.gz	ah100040060sxs_p0px1010_cl.evt.gz
SXI HK		ah100040060sxi_a0.hk.gz
SXI EVT UF		ah100040060sxi_p110000360_uf.evt.gz ah100040060sxi_p210000360_uf.evt.gz ah100040060sxi_p310000360_uf.evt.gz ah100040060sxi_p410000360_uf.evt.gz ah100040060sxi_p510000360_uf.evt.gz
SXI HOTPIX		ah100040060sxi_a010000360.hpix.gz
SXI FLICKPIX		ah100040060sxi_a110000360.fpix.gz ah100040060sxi_a210000360.fpix.gz ah100040060sxi_a310000360.fpix.gz ah100040060sxi_a410000360.fpix.gz ah100040060sxi_a510000360.fpix.gz
SXI BAD PIXEL IMG		ah100040060sxi_p110000360.bimg.gz ah100040060sxi_p210000360.bimg.gz ah100040060sxi_p310000360.bimg.gz ah100040060sxi_p410000360.bimg.gz ah100040060sxi_p510000360.bimg.gz
SXI TEL		ah100040060sxi_tel.gti.gz
SXI EVT CL		ah100040060sxi_p110000360_cl.evt.gz ah100040060sxi_p210000360_cl.evt.gz ah100040060sxi_p310000360_cl.evt.gz ah100040060sxi_p410000360_cl.evt.gz ah100040060sxi_p510000360_cl.evt.gz

Additional Files

Additional text files for analysis are as follows, and are shown in detail as they are used.

- standard extraction region files (place in dir /full/path/to/regions), XMM image, lists of SXI files to input into addascaspec
 - perseus_offset_sky.reg
 - perseus_center_sky.reg
 - ah100040030sxs_detreg.reg
 - adapt-400-7200_subimage1.fits
 - addascaspec.in

Note on sequences.

There are three Perseus distinct pointings represented among the six sequences; the nucleus is outside of the SXS FoV for 100040010, near the center of the SXS array for 100040060, and offset from the center (but still on the array) for 100040020, 100040030, 100040040, and 100040050. The data for the latter four sequences may, therefore, be combined. Only 100040060 includes SXI data; none of the sequences have HXI or SGD data.

Non-Instrument Specific Processing

ahcalctime

100040030

(1) Recalculate time for HK and unfiltered event files (~9 min)

For illustrative purposes the task is run may be run without time-sorting, which reduces the runtime by a factor of ~10 for files where time becomes out-of-order after re-assignment. In actual applications, set `sorttime=yes`, as downstream tasks expect event files to be sorted in time.

```
ahcalctime indir=data/100040030 outdir=data/100040030_ahcalctime_output  
verify_input=no sorttime=yes timecol=TIME clobber=yes  
  
mkdir data/100040030_ahcalctime_output/logs  
mv *log data/100040030_ahcalctime_output/logs
```

ahpipeline

100040060

(1) Recalibrate and rescreen data for all instruments using ahpipeline (~120 min)

```
ahpipeline indir=data/100040060 outdir=data/100040060_repro_all  
steminputs=ah100040060 stemoutputs=DEFAULT entry_stage=1 exit_stage=2  
instrument=ALL verify_input=no create_ehkmkf=yes seed=7 clobber=yes chatter=2  
mode=hl  
  
mkdir data/100040060_repro_all/logs  
mv *log data/100040060_repro_all/logs
```

Instrument Specific Reprocessing

100040030

SXS

(1) Recalibrate/rescreen using ahpipeline (~ 7 min)

New files ehk and mkf files are created and applied.

```
ahpipeline indir=data/100040030 outdir=data/100040030_repro_sxs  
steminputs=ah100040030 stemoutputs=DEFAULT entry_stage=1 exit_stage=2  
instrum=SXS verify_input=no create_ehkmkf=yes seed=7 clobber=yes chatter=2  
mode=hl  
  
mkdir data/100040030_repro_sxs/logs  
mv *log data/100040030_repro_sxs/logs
```

(2) Recalibrate/rescreen using sxspipeline (~3 min)

Original ehk and mkf files are applied.

```
sxspipeline indir=data/100040030 outdir=data/100040030_repro2_sxs  
steminputs=ah100040030 stemoutputs=ah100040030 entry_stage=1 exit_stage=2  
attitude=data/100040030/auxil/ah100040030.att.gz  
orbit=data/100040030/auxil/ah100040030.orb.gz  
obsgti=data/100040030/auxil/ah100040030_gen.gti.gz  
housekeeping=data/100040030/sxs/hk/ah100040030sxs_a0.hk1.gz  
timfile=data/100040030/auxil/ah100040030.tim.gz  
extended_housekeeping=data/100040030/auxil/ah100040030.ehk.gz  
makefilter=data/100040030/auxil/ah100040030.mkf.gz seed=7 clobber=yes chatter=2  
mode=hl  
  
mkdir data/100040030_repro2_sxs/logs  
mv *log data/100040030_repro2_sxs/logs
```

100040010

SXS

For this sequence only the `sxsgain` `extraspread` parameter must be changed from its default value of 40 to 100.

(1) Recalibrate/rescreen using ahpipeline

New files ehk and mkf files are created and applied.

```
ahpipeline indir=data/100040010 outdir=data/100040010_repro_sxs  
steminputs=ah100040010 stemoutputs=DEFAULT entry_stage=1 exit_stage=2  
instrum=SXS verify_input=no create_ehkmkf=yes extraspread=100 seed=7  
clobber=yes chatter=2 mode=hl  
  
mkdir data/100040010_repro_sxs/logs  
mv *log data/100040010_repro_sxs/logs
```

(1) Recalibrate/rescreen using sxspipeline

Original ehk and mkf files are applied.

```
sxspipeline indir=data/100040010 outdir=data/100040010_repro2_sxs/sxs  
steminputs=ah100040010 stemoutputs=ah100040010 entry_stage=1 exit_stage=2  
attitude=data/100040010/auxil/ah100040010.att.gz  
orbit=data/100040010/auxil/ah100040010.orb.gz  
obsgti=data/100040010/auxil/ah100040010_gen.gti.gz  
housekeeping=data/100040010/sxs/hk/ah100040010sxs_a0.hk1.gz  
timfile=data/100040010/auxil/ah100040010.tim.gz  
extended_housekeeping=data/100040010/auxil/ah100040010.ehk.gz  
makefilter=data/100040010/auxil/ah100040010.mkf.gz seed=7 extraspread=100  
clobber=yes chatter=2 mode=hl  
  
mkdir data/100040010_repro2_sxs/logs  
mv *log data/100040010_repro2_sxs/logs
```

Extracting Products

This section details tools to run on cleaned event files to get instrument specific data products. These may be applied to the original cleaned event files from the pipeline, or to new cleaned event files created using

the steps in the last section. In what follows, the original pipeline cleaned event files are used. The extraction region files used are assumed to be in the “regions” directory.

100040030

SXS

All newly created output files in this section are placed in the /full/path/to/data/sxs_products directory

```
cd /full/path/  
mkdir data/products_sxs  
cd data/products_sxs
```

(1) Additional screening

Create a “cleaned-2” SXS event file

```
ah100040030sxs_p0px1010_cl2.evt
```

by applying a RISETIME cut to Hp, Mp, Ms, and Lp (but not Ls) events.

```
ftselect  
infile='..../100040030/sxs/event_cl/ah100040030sxs_p0px1010_cl.evt.gz[events]'  
outfile=ah100040030sxs_p0px1010_cl2.evt expression="(PI>=400)&&((RISE_TIME>=40  
&& RISE_TIME<=60 && ITYPE<4) || (ITYPE==4))"
```

Note that the current pipeline screening already excludes events with PI<600.

(2) Extract image using xselect; construct pixel overlay and calculate NGC 1275 DET coordinate position and sky position of the center of the SXS based on nominal pointing.

```
fkeyprint ah100040030sxs_p0px1010_cl2.evt+1 PA_NOM  
PA_NOM = 253.062747813964 / [deg] Nominal aspect point roll.  
  
fkeyprint ah100040030sxs_p0px1010_cl2.evt+1 RA_NOM  
RA_NOM = 49.9326794742947 / [deg] Nominal aspect point R.A.  
  
fkeyprint ah100040030sxs_p0px1010_cl2.evt+1 DEC_NOM  
DEC_NOM = 41.5215474535011 / [deg] Nominal aspect point Dec.  
  
ahmkregion instrume=SXS ra=49.9326794742947 dec=41.5215474535011 roll=-  
106.937252186  
  
coordpnt "49.950817,41.511725" outfile=none telescop=HITOMI instrume=SXS  
ra=49.9326794742947 dec=41.5215474535011 roll=-106.9369381 startsys=radec  
stopsys=det  
  
coordpnt: OUTX OUTY= 5.20498447 2.45144120  
  
coordpnt "3.5,3.5" outfile=none telescop=HITOMI instrume=SXS  
ra=49.9326794742947 dec=41.5215474535011 roll=-106.9369381 startsys=det  
stopsys=radec  
  
coordpnt: OUTX OUTY= 49.93377019 41.52300883  
  
xsel:SUZAKU > read events ah100040030sxs_p0px1010_cl2.evt  
xsel:HITOMI-SXS-PX_NORMAL > extract image  
xsel:HITOMI-SXS-PX_NORMAL > save image ah100040030sxs_p0px1010_cl2_sky.img  
xsel:HITOMI-SXS-PX_NORMAL > set xyname detx dety
```

```
xsel:HIOMI-SXS-PX_NORMAL > extract image
xsel:HIOMI-SXS-PX_NORMAL > save image ah100040030sxs_p0px1010_c12_det.img
```

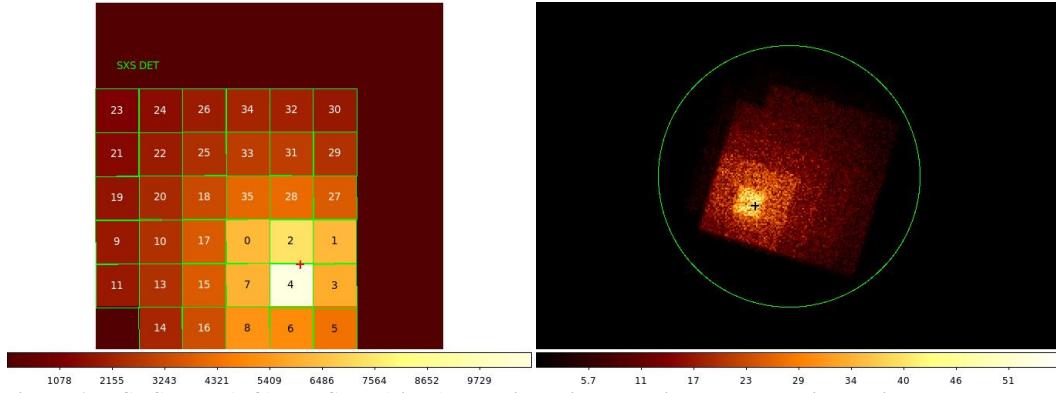


Figure 17: SXS DET (left) and SKY (right) coordinate images with DET coordinate pixel overlay (SXS.DET.text.reg) and NGC 1275 location (cross; ra=49.950817; dec=41.511725) based on nominal pointing.

(3) Extract full-array source spectra and light curves using sxsregext or xselect

Use sxsregext to extract the HP spectrum ah100040030sxs_detreg.pha from the above cleaned-2 event file events ah100040030sxs_p0px1010_c12.evt for Hp events. Here we use a circular sky region of 150 arcsec radius calculated above and shown in the above figure, perseus_offset_sky.reg,

```
# Region file format: DS9 version 4.1
global color=green dashlist=8 3 width=1 font="helvetica 10 normal roman"
select=1 highlite=1 dash=0 fixed=0 edit=1 move=1 delete=1 include=1 source=1
fk5
circle(49.93377019,41.52300883,150.0")
```

The 35-pixel detector region (ah100040030sxs_detreg.reg) and SXS exposure map (ah100040030sxs.expo) with one attitude bin are also created.

```
sxsregext infile=ah100040030sxs_p0px1010_c12.evt regmode=SKY
region=../../regions/perseus_offset_sky.reg resolist=0
outroot=ah100040030sxs_detreg outexp=ah100040030sxs.expo
ehkfile=../100040030/auxil/ah100040030.ehk.gz delta=20 numphi=1 clobber=yes
```

The content of the region file ah100040030sxs_detreg.reg is

```
physical
+box(4,1,5,1.00000000)
+box(3.5,2,6,1.00000000)
+box(3.5,3,6,1.00000000)
+box(3.5,4,6,1.00000000)
+box(3.5,5,6,1.00000000)
+box(3.5,6,6,1.00000000)
```

In addition to the spectrum, a DET coordinate image ah100040030sxs_region_SXS_det.img and lightcurve ah100040030sxs_region_SXS_det.lc are created.

Note that, by default, HP (ITYPE 0) and MP (ITYPE 1) events are included in the spectrum (this may be controlled via the hidden sxsregext resolist parameter). Also, note that the BACKSCAL keyword is set to 5.468750E-01 which is the ratio of the number of pixels used in the extraction (35) to the total detector address space in pixels (64). This is not a problem provided that any spectra to be

combined, subtracted etc. are created in the same manner. The following alternative using xselect creates a spectrum with BACKSCAL=1:

```
xsel:SUZAKU > read events ah100040030sxs_p0px1010_cl2.evt
xsel:HITOMI-SXS-PX_NORMAL > filter column "PIXEL=0:11,13:35"
xsel:HITOMI-SXS-PX_NORMAL > filter GRADE "0:0"
xsel:HITOMI-SXS-PX_NORMAL > extract spectrum
xsel:HITOMI-SXS-PX_NORMAL > save spectrum ah100040030sxs_p0px1010_cl2_HP.pi
```

Note that, since Pixel 12 events are excluded from the cleaned event files, the filtering on PIXEL is not necessary for extracting products from the entire array.

Identical steps (with the exception of the choice of sky region if using sxsregext) are applied to all 6 Perseus sequences.

100040060

SXI

All newly created output files in this section are placed in the /full/path/to/data/sxi_products directory

```
cd /full/path/
mkdir data/products_sxi
cd data/products_sxi
```

The Perseus SXI event files (sequence 100040060 only) are split into 4 files that may be combined, but not into normal and MZDYE.

Here we use a circular sky region of 150 arcsec radius shown in the figure, `perseus_center_sky.reg`, to extract products from the core region.

```
# Region file format: DS9 version 4.1
global color=green dashlist=8 3 width=1 font="helvetica 10 normal roman"
select=1 highlite=1 dash=0 fixed=0 edit=1 move=1 delete=1 include=1 source=1
fk5
circle(49.9507,41.5128,150.0")
```

(1) Extract combined images, source spectra, and light curves using xselect

```
xselect
xsel:SUZAKU > read events
.../100040060/sxi/event_cl/ah100040060sxi_p110000360_cl.evt.gz
xsel:SUZAKU > read events
.../100040060/sxi/event_cl/ah100040060sxi_p210000360_cl.evt.gz
xsel:SUZAKU > read events
.../100040060/sxi/event_cl/ah100040060sxi_p310000360_cl.evt.gz
xsel:SUZAKU > read events
.../100040060/sxi/event_cl/ah100040060sxi_p410000360_cl.evt.gz
xsel:HITOMI-SXI-WINDOW1 > filter pha_cutoff 83 1333
xsel:HITOMI-SXI-WINDOW1 > set xybin 4
xsel:HITOMI-SXI-WINDOW1 > extract image
xsel:HITOMI-SXI-WINDOW1 > save image ah100040060sxi_cl.img
xsel:HITOMI-SXI-WINDOW1 > plot image
xsel:HITOMI-SXI-WINDOW1 > clear pha_cutoff
xsel:HITOMI-SXI-WINDOW1 > filter region ../../regions/perseus_center_sky.reg
xsel:HITOMI-SXI-WINDOW1 > extract spectrum
xsel:HITOMI-SXI-WINDOW1 > plot spectrum
```

```
xsel: HITOMI-SXI-WINDOW1 > extract curve exposure=0.0
xsel: HITOMI-SXI-WINDOW1 > save curve ah100040060sxi_cl.lc
xsel: HITOMI-SXI-WINDOW1 > plot curve
```

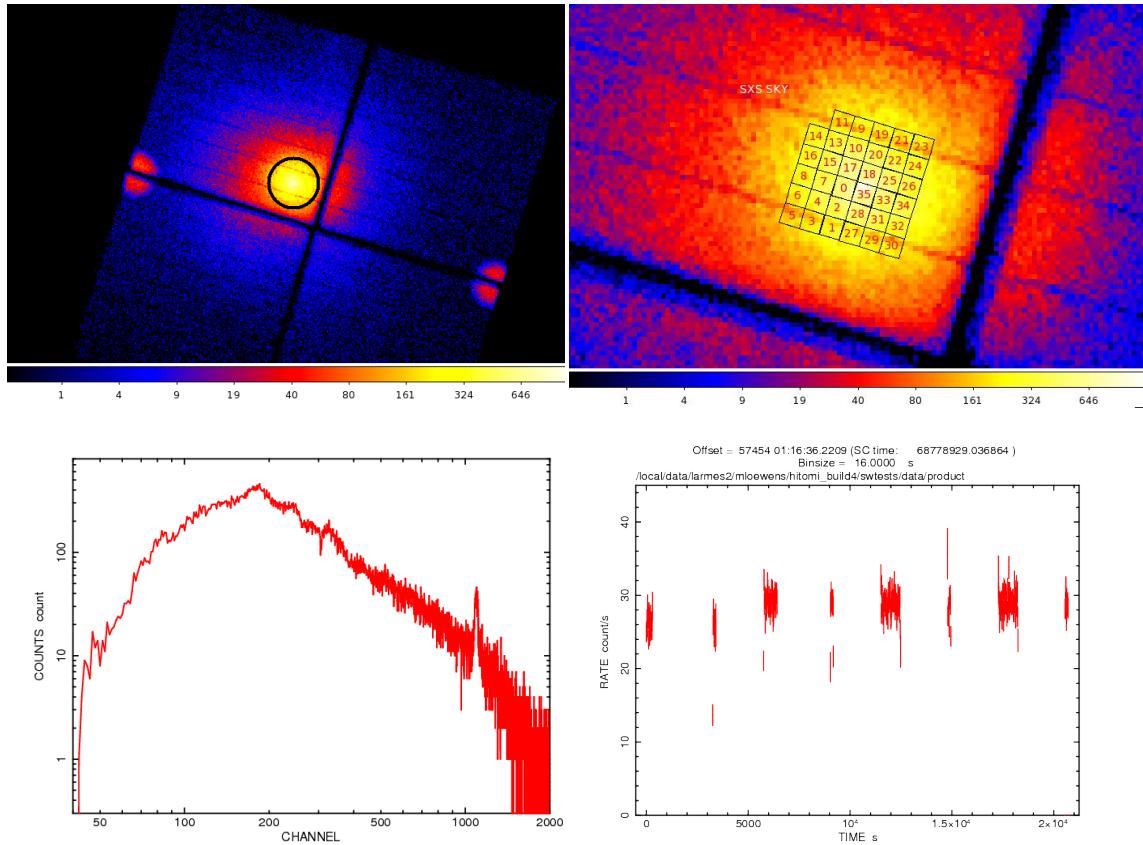


Figure 18: SXI image with extraction region (top left) and SXS FoV (SXS.SKY.text.reg; see below) corresponding to nominal pointing; and, core region lightcurve (bottom left) and (log-log scale) spectrum (bottom right) for sequence 100040060.

(2) Extract individual source spectra using xselect

Due to differences in the number of bad pixels between OBSIDs, the SXI event data cannot be combined in the same way as the other instruments. Instead, spectra, RMFs, exposure maps, and ARFs must be generated for each OBSID separately and then simultaneously combined at the end.

```
xselect
xsel: SUZAKU > read events
.../100040060/sxi/event_cl/ah100040060sxi_p110000360_cl.evt.gz
xsel: HITOMI-SXI-WINDOW1 > filter region .../regions/perseus_center_sky.reg
xsel: HITOMI-SXI-WINDOW1 > extract spectrum
xsel: HITOMI-SXI-WINDOW1 > save spectrum ah100040060sxi_p110000360_cl.pi

xselect
xsel: SUZAKU > read events
.../100040060/sxi/event_cl/ah100040060sxi_p210000360_cl.evt.gz
xsel: HITOMI-SXI-WINDOW1 > filter region .../regions/perseus_center_sky.reg
xsel: HITOMI-SXI-WINDOW1 > extract spectrum
xsel: HITOMI-SXI-WINDOW1 > save spectrum ah100040060sxi_p210000360_cl.pi

xselect
xsel: SUZAKU > read events
.../100040060/sxi/event_cl/ah100040060sxi_p310000360_cl.evt.gz
xsel: HITOMI-SXI-WINDOW1 > filter region .../regions/perseus_center_sky.reg
```

```

xsel: HITOMI-SXI-WINDOW1 > extract spectrum
xsel: HITOMI-SXI-WINDOW1 > save spectrum ah100040060sxi_p310000360_c1.pi

xselect
xsel: SUZAKU > read events
.. /100040060/sxi/event_cl/ah100040060sxi_p410000360_c1.evt.gz
xsel: HITOMI-SXI-WINDOW1 > filter region .. /regions/perseus_center_sky.reg
xsel: HITOMI-SXI-WINDOW1 > extract spectrum
xsel: HITOMI-SXI-WINDOW1 > save spectrum ah100040060sxi_p410000360_c1.pi

```

SXS

All newly created output files in this section are placed in the /full/path/to/data/sxs_products directory

(1) Additional screening

Create a “cleaned-2” SXS event file

```
ah100040060sxs_p0px1010_c12.evt
```

by applying a RISETIME cut to Hp, Mp, Ms, and Lp (but not Ls) events.

```

ftselect
infile='.. /100040060/sxs/event_cl/ah100040060sxs_p0px1010_c1.evt.gz[events]'
outfile=ah100040060sxs_p0px1010_c12.evt expression="(PI>=400)&&((RISE_TIME>=40
&& RISE_TIME<=60 && ITYPE<4) || (ITYPE==4))"

```

Note that the current pipeline screening already excludes events with PI<600.

(2) Extract image using xselect; construct pixel overlay and calculate NGC 1275 DET coordinate position based on nominal pointing.

```

fkeyprint ah100040060sxs_p0px1010_c12.evt+1 PA_NOM
PA_NOM = 253.077569456798 / [deg] Nominal aspect point roll.

fkeyprint ah100040060sxs_p0px1010_c12.evt+1 RA_NOM
RA_NOM = 49.9513492811862 / [deg] Nominal aspect point R.A.

fkeyprint ah100040060sxs_p0px1010_c12.evt+1 DEC_NOM
DEC_NOM = 41.5136699333284 / [deg] Nominal aspect point Dec.

ahmkregion instrume=SXS ra=49.9513492811862 dec=41.5136699333284 roll=-
106.922430543

coordpnt "49.950817,41.511725" outfile=none telescop=HITOMI instrume=SXS
ra=49.9513492811862 dec=41.5136699333284 roll=-106.922430543 startsys=radec
stopsys=det

coordpnt: OUTX OUTY= 3.84128410 3.75311550

xsel: SUZAKU > read events ah100040060sxs_p0px1010_c12.evt
xsel: HITOMI-SXS-PX_NORMAL > extract image
xsel: HITOMI-SXS-PX_NORMAL > save image ah100040060sxs_p0px1010_c12_sky.img
xsel: HITOMI-SXS-PX_NORMAL > set xyname detx dety
xsel: HITOMI-SXS-PX_NORMAL > extract image
xsel: HITOMI-SXS-PX_NORMAL > save image ah100040060sxs_p0px1010_c12_det.img

```

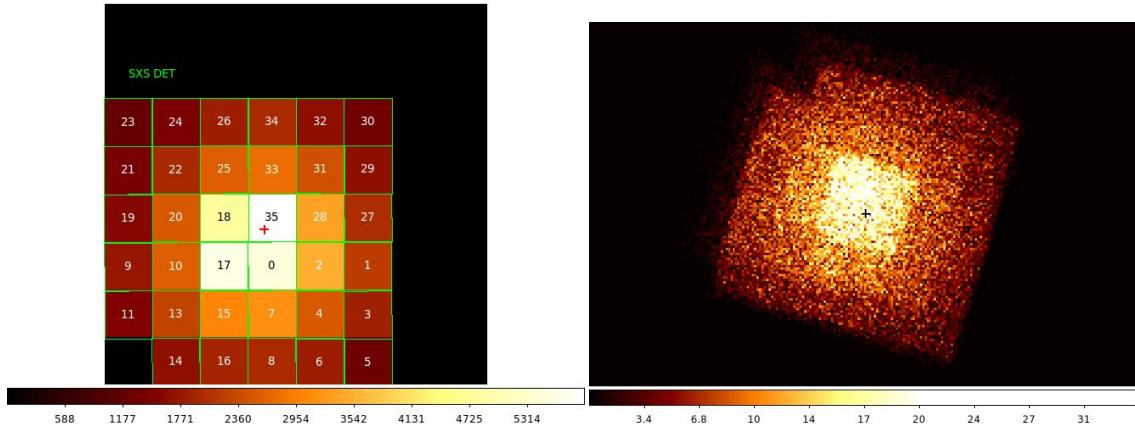


Figure 19: : SXS DET (left) and SKY (right) coordinate image with DET coordinate pixel overlay (SXS.DET.text.reg) and NGC 1275 location (cross; ra=49.950817; dec=41.511725) based on nominal pointing.

(3) Extract full-array source spectra and light curves using sxsregext or xselect

Use sxsregext to extract the HP spectrum ah100040060sxs_detreg.pha from the above cleaned-2 event file events ah100040060sxs_p0px1010_c12.evt for Hp events. Here we use a circular sky region defined above, peresus_center_sky.reg.

The 35-pixel detector region (ah100040060sxs_detreg.reg) and SXS exposure map (ah100040060sxs.expo) with one attitude bin are also created.

```
sxsregext infile=ah100040060sxs_p0px1010_c12.evt regmode=SKY
region=../../regions/perseus_center_sky.reg resolist=0
outroot=ah100040060sxs_detreg outexp=ah100040060sxs.expo
ehkfile=../100040060/auxil/ah100040060.ehk.gz delta=20 numphi=1 clobber=yes
```

The content of the region file ah100040060sxs_detreg.reg is

```
physical
+box(4,1,5,1.00000000)
+box(3.5,2,6,1.00000000)
+box(3.5,3,6,1.00000000)
+box(3.5,4,6,1.00000000)
+box(3.5,5,6,1.00000000)
+box(3.5,6,6,1.00000000)
```

In addition to the spectrum, a DET coordinate image ah100040060sxs_region_sxs_det.img and lightcurve ah100040060sxs_region_sxs_det.lc are created.

Note that, by default, HP (ITYPE 0) and MP (ITYPE 1) events are included in the spectrum (this may be controlled via the hidden sxsregext resolist parameter). Also, note that the BACKSCAL keyword is set to 5.468750E-01 which is the ratio of the number of pixels used in the extraction (35) to the total detector address space in pixels (64). This is not a problem provided that any spectra to be combined, subtracted etc. are created in the same manner. The following alternative using xselect creates a spectrum with BACKSCAL=1:

```
xsel:SUZAKU > read events ah100040060sxs_p0px1010_c12.evt
xsel:HITOMI-SXS-PX_NORMAL > filter column "PIXEL=0:11,13:35"
xsel:HITOMI-SXS-PX_NORMAL > filter GRADE "0:0"
xsel:HITOMI-SXS-PX_NORMAL > extract spectrum
xsel:HITOMI-SXS-PX_NORMAL > save spectrum ah100040060sxs_p0px1010_c12_HP.pi
```

Note that, since Pixel 12 events are excluded from the cleaned event files, the filtering on PIXEL is not necessary for extracting products from the entire array.

100040020, 100040030, 100040040, 100040050 combined

SXS

Extract products from the combined data from the four Persus Cluster observations with similar pointings.

All newly created output files in this section are placed in the /full/path/to/data/sxs_products directory

```
cd /full/path/
```

```
cd data/products_sxs
```

i) combine the event files in xselect

```
xselect
xsel:SUZAKU > read events
xsel:HITOMI-SXS-PX_NORMAL > read events
..../100040020/sxs/event_cl/ah100040020sxs_p0px1010_cl.evt.gz
xsel:HITOMI-SXS-PX_NORMAL > read events
..../100040030/sxs/event_cl/ah100040030sxs_p0px1010_cl.evt.gz
xsel:HITOMI-SXS-PX_NORMAL > read events
..../100040040/sxs/event_cl/ah100040040sxs_p0px1010_cl.evt.gz
xsel:HITOMI-SXS-PX_NORMAL > read events
..../100040050/sxs/event_cl/ah100040050sxs_p0px1010_cl.evt.gz
xsel:HITOMI-SXS-PX_NORMAL > extract events
xsel:HITOMI-SXS-PX_NORMAL > save events ah100040023450sxs_p0px1010_cl.evt
```

ii) apply the extra rise-time screening

```
ftselect infile='ah100040023450sxs_p0px1010_cl.evt[events]'
outfile=ah100040023450sxs_p0px1010_cl2.evt
expression="(PI>=400)&&((RISE_TIME>=40 && RISE_TIME<=60 &&
ITYPE<4) || (ITYPE==4))"
```

Note that the current pipeline screening already excludes events with PI<600.

iii) extract the HP spectrum, lightcurve, images

```
xsel:SUZAKU > read events ah100040023450sxs_p0px1010_cl2.evt
xsel:HITOMI-SXS-PX_NORMAL > filter column "PIXEL=0:11,13:35"
xsel:HITOMI-SXS-PX_NORMAL > filter GRADE "0:0"
xsel:HITOMI-SXS-PX_NORMAL > filter pha_cutoff 4000 20000
xsel:HITOMI-SXS-PX_NORMAL > extract image
xsel:HITOMI-SXS-PX_NORMAL > save image ah100040023450sxs_p0px1010_cl2.img
xsel:HITOMI-SXS-PX_NORMAL > plot image
xsel:HITOMI-SXS-PX_NORMAL > clear pha_cutoff
xsel:HITOMI-SXS-PX_NORMAL > extract spectrum
xsel:HITOMI-SXS-PX_NORMAL > save spectrum ah100040023450sxs_p0px1010_cl2_HP.pi
xsel:HITOMI-SXS-PX_NORMAL > extract curve
xsel:HITOMI-SXS-PX_NORMAL > save curve ah100040023450sxs_p0px1010_cl2_HP.lc
xsel:HITOMI-SXS-PX_NORMAL > plot curve
```

Generating Exposure Map, RMF, and ARF

100040030

SXS

(1) Generate the RMF

Here we use the “small” size option (includes Gaussian core only). Change whichrmf parameter to “m” to also include low energy, to “l” to also include escape peaks, “x” to also include the low energy continuum. The DET coordinate region file ah100040030sxs_detreg.reg created by sxsregext is input.

```
sxsmkrmf infile=ah100040030sxs_p0px1010_c12.evt
outfile=ah100040030_sxs_c12_HP_small.rmf resolist=0 regmode=det
regionfile=ah100040030sxs_detreg.reg whichrmf=m
```

(2) Regenerate the SXS exposure maps

Note: The exposure maps created with sxsregext are replaced using the parameters delta=20.0, numphi=1 to assure that map includes only a single attitude bin. This assumes that the attitude is stable relative to the size of the PSF and extraction region. We also account for the lost event gti per pixel here by setting the pixgtifile parameter to ah100040030sxs_px1010_exp.gti.gz -- this should be done if the lost event gti are not used in the screening (as in the standard pipeline).

```
ahexpmap ehkfile=../100040030/auxil/ah100040030.ehk.gz
gtifile=ah100040030sxs_p0px1010_c12.evt instrume=SXS badimgfile=NONE
pixgtifile=../100040030/sxs/event_uf/ah100040030sxs_px1010_exp.gti.gz
outfile=ah100040030sxs_p0px1010.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100040030sxs_p0px1010.log
```

(3) Generate the SXS ARF

The runtimes estimated below are for the case above where the exposure map has a single attitude bin. The parameter numphoton may need to be decreased to accommodate a larger number of attitude bins. Note that the source_ra and source_dec parameters are set to the NGC 1275 coordinates. The region file used is the one in DET coordinates previously created by sxsregext. The center of the sequence 100040060 SXI extraction region is used as the source coordinates. Note that for extended sources, the ARF gives spectral fluxes that are normalized to the input model or image.

Point Source (~37 min)

```
aharfgen xrtevtfile=raytrace_ah100040030sxs_p0px1010_ptsrc.fits
source_ra=49.9507 source_dec=41.5128 telescop=HITOMI instrume=SXS
emapfile=ah100040030sxs_p0px1010.expo regmode=DET
regionfile=ah100040030sxs_detreg.reg sourcetype=POINT
rmffile=ah100040030_sxs_c12_HP_small.rmf erange="0.5 17.0 0 0"
outfile=ah100040030sxs_p0px1010_ptsrc.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamofile=CALDB obffile=CALDB fwfile=CALDB
gatevalvefile=CALDB onaxisffile=CALDB onaxiscfle=CALDB mirrorfile=CALDB
obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB
scatterfile=CALDB mode=h clobber=yes seed=7
logfile=make_arf_ah100040030sxs_p0px1010_ptsrc.log
```

Extended Source, Beta-model (~38 min)

The photon distribution is assumed to follow a beta-model with 2 arcmin core radius, beta=0.47 extending to 5.7 arcmin.

```
aharfgen xrtevtfile=raytrace_ah100040030sxs_p0px1010_beta.fits
source_ra=49.9507 source_dec=41.5128 telescop=HITOMI instrume=SXS
emapfile=ah100040030sxs_p0px1010.expo regmode=DET
regionfile=ah100040030sxs_detreg.reg sourcetype=beta model betapars="2.0 0.47
5.7" rmffile=ah100040030_sxs_cl2_HP_small.rmf erange="0.5 17.0 0 0"
outfile=ah100040030sxs_p0px1010_beta.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamofile=CALDB obffile=CALDB fwfile=CALDB
gatevalvefile=CALDB onaxisffile=CALDB onaxiscfle=CALDB mirrorfile=CALDB
obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB
scatterfile=CALDB mode=h clobber=yes seed=7
logfile=make_arf_ah100040030sxs_p0px1010_beta.log
```

Extended Source, XMM image (~43 min)

The photon distribution is determined by a subimage based on XMM observations of the Perseus Cluster (original image provided by Dr. Daniel Wik).

```
aharfgen xrtevtfile=raytrace_ah100040030sxs_p0px1010_xmmimg.fits
source_ra=49.9507 source_dec=41.5128 telescop=HITOMI instrume=SXS
emapfile=ah100040030sxs_p0px1010.expo regmode=DET
regionfile=ah100040030sxs_detreg.reg sourcetype=image imgfile=adapt-400-
7200_subimage1.fits rmffile=ah100040030_sxs_cl2_HP_small.rmf erange="0.5 17.0
2.0 8.0" outfile=ah100040030sxs_p0px1010_xmmimg.arf numphoton=300000
minphoton=1 teldeffile=CALDB qefile=CALDB contamofile=CALDB obffile=CALDB
fwfile=CALDB gatevalvefile=CALDB onaxisffile=CALDB onaxiscfle=CALDB
mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB backreffile=CALDB
pcolreffile=CALDB scatterfile=CALDB mode=h clobber=yes seed=7
logfile=make_arf_ah100040030sxs_p0px1010_xmmimg.log
```

100040060

SXI

Note that because the cosmic ray echo effect varies between sequences over the course of the observation, a single bad image file cannot be used below. In general this should be checked when deriving SXI spectral ARFs for combined OBSIDs. If they differ as they do here, separate RMF and ARF files should be derived, and the spectra and responses should then be co-added, or individual spectra should be simultaneously fit.

All newly created output files in this section are placed in the /full/path/to/data/sxi_products directory

```
cd /full/path/
cd data/products_sxi
```

(1) Create an RMF for each source spectrum

```
sxirmf infile=ah100040060sxi_p110000360_cl.pi
outfile=ah100040060sxi_p110000360_cl.rmf clobber=yes mode=h1

sxirmf infile=ah100040060sxi_p210000360_cl.pi
outfile=ah100040060sxi_p210000360_cl.rmf clobber=yes mode=h1

sxirmf infile=ah100040060sxi_p310000360_cl.pi
outfile=ah100040060sxi_p310000360_cl.rmf clobber=yes mode=h1

sxirmf infile=ah100040060sxi_p410000360_cl.pi
outfile=ah100040060sxi_p410000360_cl.rmf clobber=yes mode=h1
```

(2) Create an Exposure Map for each source spectrum

The exposure maps (and flatfield images below) are created with the parameters `delta=20.0`, `numphi=1` to assure that the map includes only a single attitude bin, i.e. assuming that the attitude is stable relative to the size of the PSF and extraction region.

```
ahexpmap ehkfile=../100040060/auxil/ah100040060.ehk.gz
gtifile=../100040060/sxi/event_cl/ah100040060sxi_p110000360_cl.evt.gz
instrume=SXI
badimgfile=../100040060/sxi/event_uf/ah100040060sxi_p110000360.bimg.gz
pixgtifile=../100040060/sxi/event_uf/ah100040060sxi_a110000360.fpix.gz
outfile=ah100040060sxi_p110000360.expo outmaptyle=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100040060sxi_p110000360.log

ahexpmap ehkfile=../100040060/auxil/ah100040060.ehk.gz
gtifile=../100040060/sxi/event_cl/ah100040060sxi_p210000360_cl.evt.gz
instrume=SXI
badimgfile=../100040060/sxi/event_uf/ah100040060sxi_p210000360.bimg.gz
pixgtifile=../100040060/sxi/event_uf/ah100040060sxi_a210000360.fpix.gz
outfile=ah100040060sxi_p210000360.expo outmaptyle=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100040060sxi_p210000360.log

ahexpmap ehkfile=../100040060/auxil/ah100040060.ehk.gz
gtifile=../100040060/sxi/event_cl/ah100040060sxi_p310000360_cl.evt.gz
instrume=SXI
badimgfile=../100040060/sxi/event_uf/ah100040060sxi_p310000360.bimg.gz
pixgtifile=../100040060/sxi/event_uf/ah100040060sxi_a310000360.fpix.gz
outfile=ah100040060sxi_p310000360.expo outmaptyle=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100040060sxi_p310000360.log

ahexpmap ehkfile=../100040060/auxil/ah100040060.ehk.gz
gtifile=../100040060/sxi/event_cl/ah100040060sxi_p410000360_cl.evt.gz
instrume=SXI
badimgfile=../100040060/sxi/event_uf/ah100040060sxi_p410000360.bimg.gz
pixgtifile=../100040060/sxi/event_uf/ah100040060sxi_a410000360.fpix.gz
outfile=ah100040060sxi_p410000360.expo outmaptyle=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100040060sxi_p410000360.log
```

(3) Create an ARF for each source spectrum (~32 min)

In general, the `source_ra` and `source_dec` parameters should be the coordinates of the center of the source in the image, which are not necessarily the same as the actual source coordinates. The runtime estimated above is for the case above where the exposure map has a single attitude bin. The parameter `numphoton` may need to be decreased to accommodate a larger number of attitude bins. Note that the ARF constructed below gives spectral fluxes that are normalized to the input XMM image.

```

aharfgen xrtevtfile=raytrace_ah100040060sxi_p110000360_xmmimg.fits
source_ra=49.9507 source_dec=41.5128 telescop=HITOMI instrume=SXI
emapfile=ah100040060sxi_p110000360.expo regmode=SKY
regionfile=../../regions/perseus_center_sky.reg sourcetype=image imgfile=adapt-
400-7200_subimage1.fits rmffile=ah100040060sxi_p110000360_cl.rmf erange="0.5
16.0 0.5 7.0" outfile=ah100040060sxi_p110000360_xmmimg.arf numphoton=300000
minphoton=1 teldeffile=CALDB qefile=CALDB contamofile=CALDB onaxisffile=CALDB
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB seed=7 clobber=yes
chatter=2 mode=h logfile=make_arf_ah100040060sxi_p110000360_xmmimg.log

aharfgen xrtevtfile=raytrace_ah100040060sxi_p210000360_xmmimg.fits
source_ra=49.9507 source_dec=41.5128 telescop=HITOMI instrume=SXI
emapfile=ah100040060sxi_p210000360.expo regmode=SKY
regionfile=../../regions/perseus_center_sky.reg sourcetype=image imgfile=adapt-
400-7200_subimage1.fits rmffile=ah100040060sxi_p210000360_cl.rmf erange="0.5
16.0 0.5 7.0" outfile=ah100040060sxi_p210000360_xmmimg.arf numphoton=300000
minphoton=1 teldeffile=CALDB qefile=CALDB contamofile=CALDB onaxisffile=CALDB
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB seed=7 clobber=yes
chatter=2 mode=h logfile=make_arf_ah100040060sxi_p210000360_xmmimg.log

aharfgen xrtevtfile=raytrace_ah100040060sxi_p310000360_xmmimg.fits
source_ra=49.9507 source_dec=41.5128 telescop=HITOMI instrume=SXI
emapfile=ah100040060sxi_p310000360.expo regmode=SKY
regionfile=../../regions/perseus_center_sky.reg sourcetype=image imgfile=adapt-
400-7200_subimage1.fits rmffile=ah100040060sxi_p310000360_cl.rmf erange="0.5
16.0 0.5 7.0" outfile=ah100040060sxi_p310000360_xmmimg.arf numphoton=300000
minphoton=1 teldeffile=CALDB qefile=CALDB contamofile=CALDB onaxisffile=CALDB
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB seed=7 clobber=yes
chatter=2 mode=h logfile=make_arf_ah100040060sxi_p310000360_xmmimg.log

aharfgen xrtevtfile=raytrace_ah100040060sxi_p410000360_xmmimg.fits
source_ra=49.9507 source_dec=41.5128 telescop=HITOMI instrume=SXI
emapfile=ah100040060sxi_p410000360.expo regmode=SKY
regionfile=../../regions/perseus_center_sky.reg sourcetype=image imgfile=adapt-
400-7200_subimage1.fits rmffile=ah100040060sxi_p410000360_cl.rmf erange="0.5
16.0 0.5 7.0" outfile=ah100040060sxi_p410000360_xmmimg.arf numphoton=300000
minphoton=1 teldeffile=CALDB qefile=CALDB contamofile=CALDB onaxisffile=CALDB
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB seed=7 clobber=yes
chatter=2 mode=h logfile=make_arf_ah100040060sxi_p410000360_xmmimg.log

```

(4) Combine SXI spectra and responses

The ftool ‘addascaspec’ should be used to combine the source spectra and responses.

```
addascaspec addascaspec.in ah100040060sxi_cl.pi ah100040060sxi_cl.rsp "POISS-0"
```

where the file ‘addascaspec.in’ contains the following four lines (delineated by ‘\’):

```

ah100040060sxi_p110000360_cl.pi ah100040060sxi_p210000360_cl.pi \
ah100040060sxi_p310000360_cl.pi ah100040060sxi_p410000360_cl.pi \
ah100040060sxi_p110000360_xmmimg.arf ah100040060sxi_p210000360_xmmimg.arf \
ah100040060sxi_p310000360_xmmimg.arf ah100040060sxi_p410000360_xmmimg.arf \
ah100040060sxi_p110000360_cl.rmf ah100040060sxi_p210000360_cl.rmf \
ah100040060sxi_p310000360_cl.rmf ah100040060sxi_p410000360_cl.rmf

```

This will create a combined source spectrum, and a single .rsp file containing both the combined RMF and ARF.

(5) Create an efficiency map (flat field) for each OBSID

```

ahexpmap ehkfile=../100040060/auxil/ah100040060.ehk.gz
gtifile=../100040060/sxi/event_cl/ah100040060sxi_p110000360_cl.evt.gz
instrume=SXI
badimgfile=../100040060/sxi/event_uf/ah100040060sxi_p110000360.bimg.gz
pixgtifile=../100040060/sxi/event_uf/ah100040060sxi_a110000360.fpix.gz
outfile=ah100040060sxi_p110000360.flat outmappytype=EFFICIENCY delta=20.0
numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_flat_ah100040060sxi_p110000360.log

ahexpmap ehkfile=../100040060/auxil/ah100040060.ehk.gz
gtifile=../100040060/sxi/event_cl/ah100040060sxi_p210000360_cl.evt.gz
instrume=SXI
badimgfile=../100040060/sxi/event_uf/ah100040060sxi_p210000360.bimg.gz
pixgtifile=../100040060/sxi/event_uf/ah100040060sxi_a210000360.fpix.gz
outfile=ah100040060sxi_p210000360.flat outmappytype=EFFICIENCY delta=20.0
numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_flat_ah100040060sxi_p210000360.log

ahexpmap ehkfile=../100040060/auxil/ah100040060.ehk.gz
gtifile=../100040060/sxi/event_cl/ah100040060sxi_p310000360_cl.evt.gz
instrume=SXI
badimgfile=../100040060/sxi/event_uf/ah100040060sxi_p310000360.bimg.gz
pixgtifile=../100040060/sxi/event_uf/ah100040060sxi_a310000360.fpix.gz
outfile=ah100040060sxi_p310000360.flat outmappytype=EFFICIENCY delta=20.0
numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_flat_ah100040060sxi_p310000360.log

ahexpmap ehkfile=../100040060/auxil/ah100040060.ehk.gz
gtifile=../100040060/sxi/event_cl/ah100040060sxi_p410000360_cl.evt.gz
instrume=SXI
badimgfile=../100040060/sxi/event_uf/ah100040060sxi_p410000360.bimg.gz
pixgtifile=../100040060/sxi/event_uf/ah100040060sxi_a410000360.fpix.gz
outfile=ah100040060sxi_p410000360.flat outmappytype=EFFICIENCY delta=20.0
numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_flat_ah100040060sxi_p410000360.log

```

SXS

The steps are identical to those above for sequence 100040020.

100040020, 100040030, 100040040, 100040050 combined

(1) Generate the RMF

Here we use the “small” size option (includes Gaussian core only). Change whichrmf parameter to “m” to also include low energy, to “l” to also include escape peaks, “x” to also include the low energy

continuum. The DET coordinate region file ah100040030sxs_detreg.reg created by sxsregext is input.

```
sxsmkrmf infile=ah100040023450sxs_p0px1010_c12.evt
outfile=ah100040023450_sxs_c12_HP_small.rmf resolist=0 regmode=det
regionfile=ah100040030sxs_detreg.reg whichrmf=s
```

(2) Merge the necessary files from each sequence

(a) Merge the ehk files

```
ftmerge
'../100040020/auxil/ah100040020.ehk.gz,../100040030/auxil/ah100040030.ehk.gz,..
/100040040/auxil/ah100040040.ehk.gz,../100040050/auxil/ah100040050.ehk.gz'
ah100040023450.ehk
```

(b) Merge the pixgti file GTIPIXELOFF extensions

```
ftmerge
'../100040020/sxs/event_uf/ah100040020sxs_px1010_exp.gti.gz+2,../100040030/sxs/
event_uf/ah100040030sxs_px1010_exp.gti.gz+2,../100040040/sxs/event_uf/ah1000400
40sxs_px1010_exp.gti.gz+2,../100040050/sxs/event_uf/ah100040050sxs_px1010_exp.g
ti.gz+2' ah100040023450sxs_px1010_exp.gti
```

(3) Create the SXS exposure map for the combined SXS

Note: The exposure maps created using the parameters delta=20.0, numphi=1 to assure that map includes only a single attitude bin. This assumes that the attitude is stable relative to the size of the PSF and extraction region. We also account for the lost event gti per pixel here by setting the pixgtifile parameter to the merged pixgti file ah100040023450sxs_px1010_exp.gti created above.

```
ahexpmap ehkfile=ah100040023450.ehk gtifile=ah100040023450sxs_p0px1010_c12.evt
instrume=SXS badimgfile=NONE pixgtifile=ah100040023450sxs_px1010_exp.gti
outfile=ah100040023450sxs_p0px1010.expo outmaptype=EXPOSURE delta=20 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100040023450sxs_p0px1010.log
```

(4) Generate the SXS ARF

The runtimes estimated below are for the case above where the exposure map has a single attitude bin. The parameter numphoton may need to be decreased to accommodate a larger number of attitude bins. Note that the source_ra and source_dec parameters are set to the NGC 1275 coordinates. The region file used is the one in DET coordinates previously created by sxsregext. The center of the sequence 100040060 SXI extraction region is used as the source coordinates. Note that for extended sources, the ARF gives spectral fluxes that are normalized to the input model or image.

Point Source (~28 min)

```
aharfgen xrtevtfile=raytrace_ah100040023450sxs_p0px1010_ptsrc.fits
source_ra=49.9507 source_dec=41.5128 telescop=HITOMI instrume=SXS
emapfile=ah100040023450sxs_p0px1010.expo regmode=DET
regionfile=ah100040030sxs_detreg.reg sourcetype=POINT
rmffile=ah100040023450_sxs_c12_HP_small.rmf erange="0.5 17.0 0 0"
outfile=ah100040023450sxs_p0px1010_ptsrc.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamofile=CALDB obffile=CALDB fwfile=CALDB
gatevalvefile=CALDB onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB
```

```

obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB
scatterfile=CALDB mode=h clobber=yes seed=7
logfile=make_arf_ah100040023450sxs_p0px1010_ptsrc.log

```

Extended Source, Beta-model (~29 min)

The photon distribution is assumed to follow a beta-model with 2 arcmin core radius, beta=0.47 extending to 5.7 arcmin.

```

aharfgen xrtevtfile=raytrace_ah100040023450sxs_p0px1010_beta.fits
source_ra=49.9507 source_dec=41.5128 telescop=HITOMI instrume=SXS
emapfile=ah100040023450sxs_p0px1010.expo regmode=DET
regionfile=ah100040030sxs_detreg.reg sourcetype=beta model betapars="2.0 0.47
5.7" rmffile=ah100040023450_sxs_cl2_HP_small.rmf erange="0.5 17.0 0 0"
outfile=ah100040023450sxs_p0px1010_beta.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamofile=CALDB obffile=CALDB fwfile=CALDB
gatevalvefile=CALDB onaxisffile=CALDB onaxiscfle=CALDB mirrorfile=CALDB
obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB
scatterfile=CALDB mode=h clobber=yes seed=7
logfile=make_arf_ah100040023450sxs_p0px1010_beta.log

```

Extended Source, XMM image (~35 min)

The photon distribution is determined by a subimage based on XMM observations of the Perseus Cluster (original image provided by Dr. Daniel Wik).

```

aharfgen xrtevtfile=raytrace_ah100040023450sxs_p0px1010_xmmimg.fits
source_ra=49.9507 source_dec=41.5128 telescop=HITOMI instrume=SXS
emapfile=ah100040023450sxs_p0px1010.expo regmode=DET
regionfile=ah100040030sxs_detreg.reg sourcetype=image imgfile=adapt-400-
7200_subimage1.fits rmffile=ah100040023450_sxs_cl2_HP_small.rmf erange="0.5
17.0 2.0 8.0" outfile=ah100040023450sxs_p0px1010_xmmimg.arf numphoton=300000
minphoton=1 teldeffile=CALDB qefile=CALDB contamofile=CALDB obffile=CALDB
fwfile=CALDB gatevalvefile=CALDB onaxisffile=CALDB onaxiscfle=CALDB
mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB backreffile=CALDB
pcolreffile=CALDB scatterfile=CALDB mode=h clobber=yes seed=7
logfile=make_arf_ah100040023450sxs_p0px1010_xmmimg.log

```

Spectral Fitting

Notes

A binned (2 eV) spectrum is created using *grppha* as follows:

```

grppha
Please enter PHA filename[] ah100040023450sxs_p0px1010_c12_HP.pi
Please enter output filename[] ah100040023450sxs_p0px1010_c12_HP_2eV.pi
GRPPHA[group 0 32767 4] group 0 32767 4
minchan(nocom)          0
maxchan(nocom)         32767
numchan(nocom)          4
GRPPHA[] chkey respfile ah100040023450_sxs_cl2_HP_small.rmf
GRPPHA[] chkey ancrfile ah100040023450sxs_p0px1010_xmmimg.arf
GRPPHA[] exit
... written the PHA data Extension
..... exiting, changes written to file : ah100040023450sxs_p0px1010_c12_HP_2
** grppha 3.0.1 completed successfully

```

The following XSPEC settings are used below (see <http://www.atomdb.org/> for details on downloading the latest APEC model)

For fitting;

```
statistic cstat
abund lodd
xsect bcmc
xset APECROOT /path/to/apec_files/apec_v3.0.3
```

For plotting:

```
setplot rebin 3 8 (SXS)
```

Note that the spectra and response files co-added for sequences are used below; however, identical procedures apply to individual sequences.

SXS

(1) Fit the SXS spectrum in the 1.8-12 keV band with a model composed of an absorbed power-law representing the AGN and a broadened, single abundance thermal plasma model representing the ICM. The column densities and AGN power-law index are fixed following arXiv:1607.07420. The ARF derived from the XMM image is used here (and, as a result the fluxes correspond to the entire region encompassed by the image – which has ~3.5 times the flux as in the SXS FoV).

```
1 file 1 spectrum
Spectrum 1  Spectral Data File: ah100040023450sxs_p0px1010_c12_HP_2eV.pi
Net count rate (cts/s) for Spectrum:1  1.737e+00 +/- 2.741e-03
Assigned to Data Group 1 and Plot Group 1
Noticed Channels: 902-5999
Telescope: HITOMI Instrument: SXS Channel Type: PI
Exposure Time: 2.313e+05 sec
Using fit statistic: cstat
Using test statistic: chi
Using Response (RMF) File           ah100040023450_sxs_c12_HP_small.rmf for
Source 1
Using Auxiliary Response (ARF) File ah100040023450sxs_p0px1010_xmmimg.arf

Spectral data counts: 401827
Model predicted rate: 1.73729
```

Current model list:

```
=====
Model TBabs<1>*bapec<2> + TBabs<3>*powerlaw<4> Source No.: 1 Active/On
Model Model Component Parameter Unit      Value
par comp
 1   1   TBabs      nH       10^22    0.138000   frozen
 2   2   bapec      kT       keV      3.87200    +/- 2.21631E-02
 3   2   bapec      Abundanc          0.637828   +/- 7.46285E-03
 4   2   bapec      Redshift          1.76736E-02 +/- 8.70097E-06
 5   2   bapec      Velocity          km/s     185.145    +/- 2.51813
 6   2   bapec      norm                0.529256   +/- 3.76068E-03
 7   3   TBabs      nH       10^22    0.330000   frozen
 8   4   powerlaw   PhoIndex          1.80000    frozen
 9   4   powerlaw   norm                2.49439E-02 +/- 8.92344E-04
```

Using energies from responses.

```

Fit statistic : C-Statistic =      6139.288 using 5098 PHA bins and 5092
degrees of freedom.

Test statistic : Chi-Squared =      6874.022 using 5098 PHA bins.
Reduced chi-squared =      1.349965 for 5092 degrees of freedom
Null hypothesis probability = 1.556139e-57

***Warning: Chi-square may not be valid due to bins with zero variance
in spectrum number(s): 1

```

Weighting method: standard

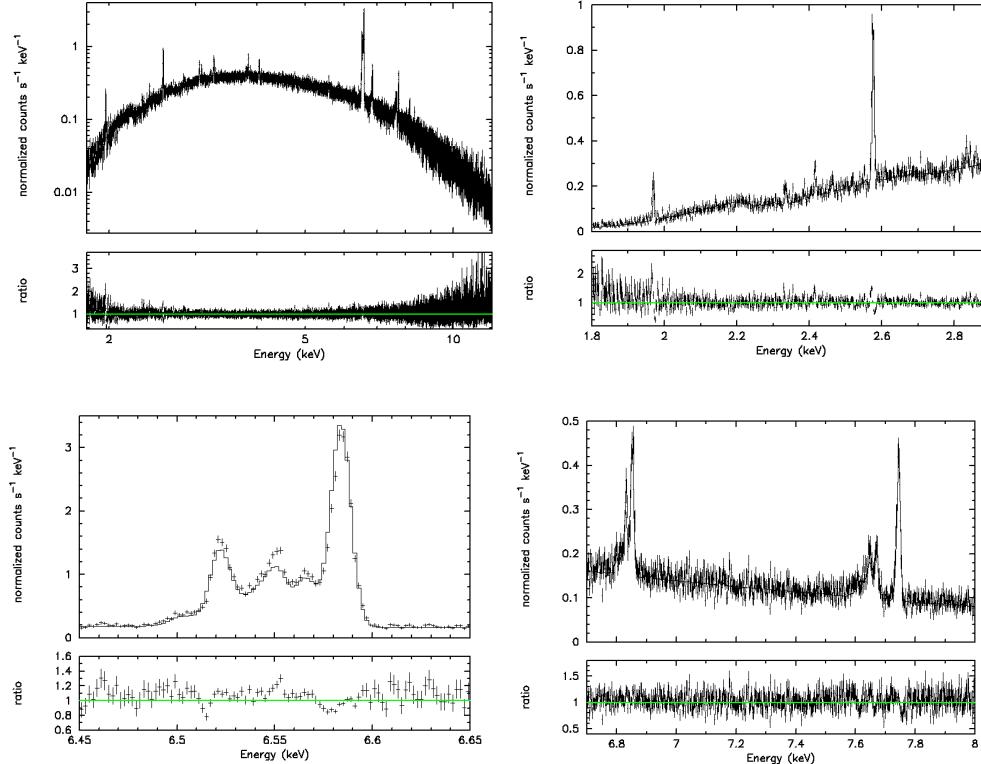


Figure 20: Fits to SXS spectra for the combined Perseus sequences 100040020, 100040030, 100040040, and 100040050 (upper left), with zooms to 1.8–2.9 keV (upper right), 6.45–6.64 keV (lower left), 6.7–8 keV (lower right).

(2) Fit the SXS spectrum in the 1.8–12 keV band with a model composed of an absorbed power-law representing the AGN and a broadened, single abundance thermal plasma model representing the ICM. The column densities and AGN power-law index are fixed following arXiv:1607.07420. The point-source ARF is used for the AGN component, and ARF derived from the beta model for the ICM.

```

1 file 1 spectrum
Spectrum 1  Spectral Data File: ah100040023450sxs_p0px1010_c12_HP_2eV.pi
Net count rate (cts/s) for Spectrum:1  1.737e+00 +/- 2.741e-03
Assigned to Data Group 1 and Plot Group 1
Noticed Channels: 902-5999
Telescope: HITOMI Instrument: SXS Channel Type: PI
Exposure Time: 2.313e+05 sec
Using fit statistic: cstat
Using test statistic: chi
Using Response (RMF) File          ah100040023450_sxs_c12_HP_small.rmf for
Source 1

```

```

Using Auxiliary Response (ARF) File ah100040023450sxs_p0px1010_beta.arf
Using Response (RMF) File ah100040023450_sxs_c12_HP_small.rmf for
Source 2
Using Auxiliary Response (ARF) File ah100040023450sxs_p0px1010_ptsrc.arf

Spectral data counts: 401827
Model predicted rate: 1.73729

```

Current model list:

```
=====
Model TBabs<1>*bapec<2> Source No.: 1 Active/On
Model Model Component Parameter Unit Value
par comp
 1   1   TBabs      nH        10^22    0.138000   frozen
 2   2   bapec      kT        keV      3.88505    +/- 2.21499E-02
 3   2   bapec      Abundanc          0.633732   +/- 7.30348E-03
 4   2   bapec      Redshift          1.76740E-02 +/- 8.70021E-06
 5   2   bapec      Velocity     km/s    185.295    +/- 2.51659
 6   2   bapec      norm           0.485346   +/- 3.35451E-03
=====
```

```
=====
Model agn:TBabs<1>*powerlaw<2> Source No.: 2 Active/On
Model Model Component Parameter Unit Value
par comp
 1   1   TBabs      nH        10^22    0.330000   frozen
 2   2   powerlaw   PhoIndex          1.80000    frozen
 3   2   powerlaw   norm           8.67254E-03 +/- 3.12955E-04
=====
```

Using energies from responses.

```
Fit statistic : C-Statistic =       6141.955 using 5098 PHA bins and 5092
degrees of freedom.
```

```
Test statistic : Chi-Squared =       6888.095 using 5098 PHA bins.
Reduced chi-squared =      1.352729 for 5092 degrees of freedom
Null hypothesis probability = 2.478201e-58
```

```
***Warning: Chi-square may not be valid due to bins with zero variance
in spectrum number(s): 1
```

Weighting method: standard

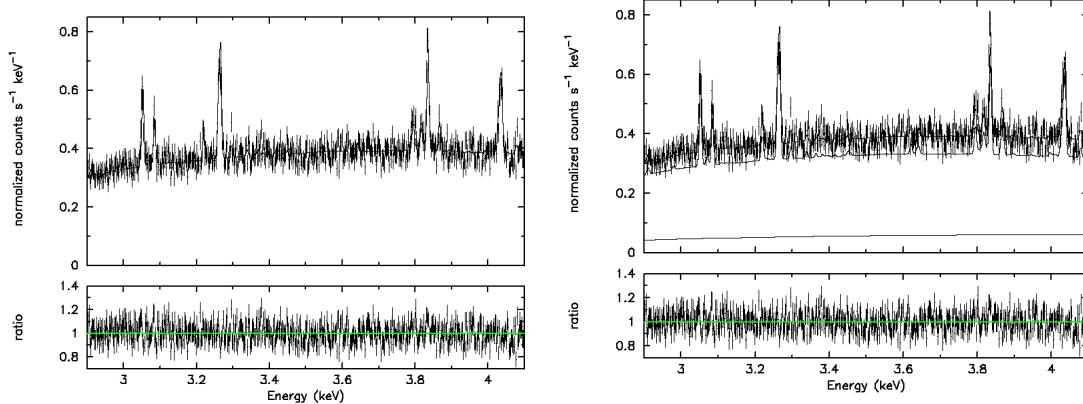


Figure 21: Fits to SXS spectra for the combined Perseus sequences 100040020, 100040030, 100040040, and 100040050 zoomed to the 2.9-4.1 keV band using the ARF derived from the XMM image (left), and the point-source ARF applied to the power-law, and the ARF derived from the beta model applied to the thermal plasma (right; with individual components).

(3) Jointly fit the SXI spectrum in the 0.8-12 keV band, and the SXS spectrum in the 1.8-12 keV band for Perseus sequence 100040060 with a model composed of an absorbed power-law representing the AGN and a broadened, single abundance thermal plasma model representing the ICM. The column densities and AGN power-law index are fixed as above, and the ARFs derived from the XMM image are used. A relative scaling of the SXS and SXI thermal components is introduced to account for the cross-calibration uncertainties – in both spectra the normalizations correspond to the fluxes normalized to the input image.

```
2 files 2 spectra
Spectrum 1 Spectral Data File: ah100040060sxs_p0px1010_cl2_HP_2eV.pi
Net count rate (cts/s) for Spectrum:1 1.948e+00 +/- 6.721e-03
Assigned to Data Group 1 and Plot Group 1
Noticed Channels: 902-5999
Telescope: HITOMI Instrument: sxs Channel Type: PI
Exposure Time: 4.312e+04 sec
Using fit statistic: cstat
Using test statistic: chi
Using Response (RMF) File           ah100040060_sxs_cl2_HP_small.rmf for
Source 1
Using Auxiliary Response (ARF) File ah100040060sxs_p0px1010_xmmimg.arf

Spectral data counts: 83990
Model predicted rate: 1.94783

Spectrum 2 Spectral Data File: ah100040060sxi_cl.pi
Net count rate (cts/s) for Spectrum:2 2.461e+01 +/- 8.391e-02
Assigned to Data Group 2 and Plot Group 2
Noticed Channels: 135-1999
Telescope: HITOMI Instrument: SXI Channel Type: PI
Exposure Time: 3495 sec
Using fit statistic: cstat
Using test statistic: chi
Using Response (RMF) File           ah100040060sxi_cl.rsp for Source 1

Spectral data counts: 86022
Model predicted rate: 24.6094
```

Current model list:

```
=====
Model constant<1>*TBabs<2>*bapec<3> + constant<4>*TBabs<5>*powerlaw<6> Source
No.: 1 Active/On
Model Model Component Parameter Unit      Value
par comp
                                Data group: 1
 1   1   constant   factor          1.00000   frozen
 2   2   TBabs     nH            10^22    0.138000  frozen
 3   3   bapec     kT            keV       3.82403  +/- 3.58489E-02
 4   3   bapec     Abundanc      0.693909  +/- 1.53828E-02
 5   3   bapec     Redshift      1.75019E-02  +/- 1.83279E-05
 6   3   bapec     Velocity     km/s      180.144  +/- 5.36617
 7   3   bapec     norm          0.507472  +/- 7.22958E-03
 8   4   constant   factor          1.00000   = p1
 9   5   TBabs     nH            10^22    0.330000  frozen
10   6   powerlaw  PhoIndex      1.80000   frozen
11   6   powerlaw  norm          2.97461E-02  +/- 1.66712E-03
                                Data group: 2
```

12	1	constant	factor		0.798375	+/-	4.86042E-03
13	2	TBabs	nH	10^{22}	0.138000	=	p2
14	3	bpec	kT	keV	3.82403	=	p3
15	3	bpec	Abundanc		0.693909	=	p4
16	3	bpec	Redshift		1.75019E-02	=	p5
17	3	bpec	Velocity	km/s	180.144	=	p6
18	3	bpec	norm		0.507472	=	p7
19	4	constant	factor		0.798375	=	p12
20	5	TBabs	nH	10^{22}	0.330000	=	p9
21	6	powerlaw	PhoIndex		1.80000	=	p10
22	6	powerlaw	norm		2.97461E-02	=	p11

Using energies from responses.

Fit statistic : C-Statistic = 7691.375 using 6963 PHA bins and 6956 degrees of freedom.

Test statistic : Chi-Squared = 8065.189 using 6963 PHA bins.
 Reduced chi-squared = 1.159458 for 6956 degrees of freedom
 Null hypothesis probability = 1.752052e-19

***Warning: Chi-square may not be valid due to bins with zero variance
 in spectrum number(s): 1 2

Weighting method: standard

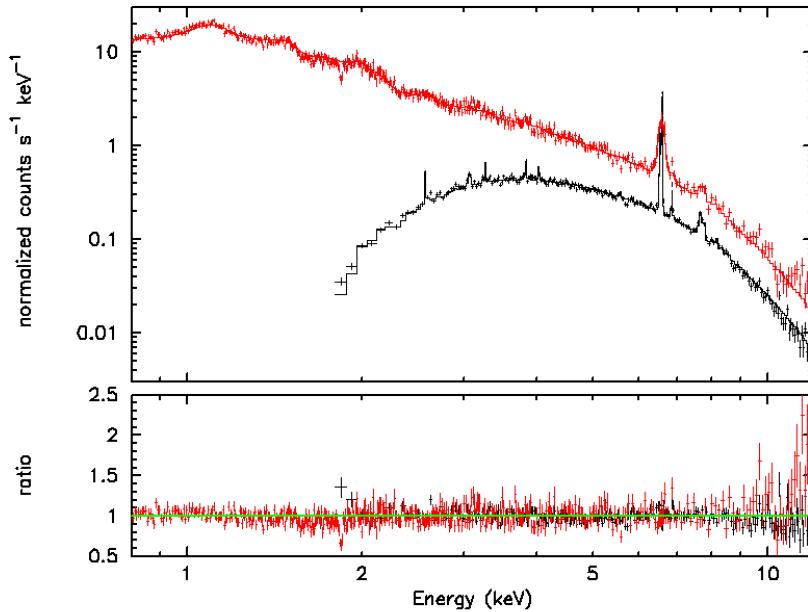


Figure 22: Joint SXI and SXS spectral fit for Perseus sequence 1000440060.

Crab Nebula

Data description

Table 5	100044010
GEN-HK	ah100044010gen_a0.hk1.gz

TIM	ah100044010.tim.gz
ATTITUDE	ah100044010.att.gz
ORBIT	ah100044010.orb.gz
OBSGTI	ah100044010_gen.gti.gz
MKF	ah100044010.mkf.gz
EHK	ah100044010.ehk.gz
EHK2	ah100044010.ehk2.gz
HXI1 HK	ah100044010hx1_a0.hk.gz
HXI2 HK	ah100044010hx2_a0.hk.gz
HXI DELTA-ATT	ah100044010hx1.att.gz
HXI DELTA-ATT	ah100044010hx2.att.gz
HXI1 CAMS	ah100044010hx1_cms.fits.gz
HXI2 CAMS	ah100044010hx2_cms.fits.gz
HXI1 SFF	ah100044010hx1_p0camrec_uf.evt.gz
HXI2 SFF	ah100044010hx2_p0camrec_uf.evt.gz
HXI1 SFFa	ah100044010hx1_p0camrec_ufa.evt.gz
HXI2 SFFa	ah100044010hx2_p0camrec_ufa.evt.gz
HXI TEL	ah100044010hx1_tel.gti.gz
HXI1 PSEUDO	ah100044010hx1_p0camrecpse_cl.evt.gz
HXI2 PSEUDO	ah100044010hx2_p0camrecpse_cl.evt.gz
HXI1 EVT CL	ah100044010hx1_p0camrec_cl.evt.gz
HXI2 EVT CL	ah100044010hx2_p0camrec_cl.evt.gz
SGD TEL	ah100044010sg1_tel.gti.gz
SGD1 HK	ah100044010sg1_a0.hk.gz
SGD1 SFF	ah100044010sg1_p0cc1rec_uf.evt.gz ah100044010sg1_p0cc2rec_uf.evt.gz ah100044010sg1_p0cc3rec_uf.evt.gz
SGD1 SFFa	ah100044010sg1_p0cc1rec_ufa.evt.gz ah100044010sg1_p0cc2rec_ufa.evt.gz ah100044010sg1_p0cc3rec_ufa.evt.gz
SGD1 PSEUDO	ah100044010sg1_p0cc1recpse_cl.evt.gz ah100044010sg1_p0cc2recpse_cl.evt.gz ah100044010sg1_p0cc3recpse_cl.evt.gz
SGD1 EVT CL	ah100044010sg1_p0cc1rec_cl.evt.gz ah100044010sg1_p0cc2rec_cl.evt.gz ah100044010sg1_p0cc3rec_cl.evt.gz
SGD2 HK	ah100044010sg2_a0.hk.gz
SGD2 SFF	ah100044010sg2_p0cc1rec_uf.evt.gz ah100044010sg2_p0cc2rec_uf.evt.gz ah100044010sg2_p0cc3rec_uf.evt.gz
SGD2 SFFa	ah100044010sg2_p0cc1rec_ufa.evt.gz ah100044010sg2_p0cc2rec_ufa.evt.gz ah100044010sg2_p0cc3rec_ufa.evt.gz
SGD2 PSEUDO	ah100044010sg2_p0cc1recpse_cl.evt.gz ah100044010sg2_p0cc2recpse_cl.evt.gz ah100044010sg2_p0cc3recpse_cl.evt.gz
SGD2 EVT CL	ah100044010sg2_p0cc1rec_cl.evt.gz ah100044010sg2_p0cc2rec_cl.evt.gz ah100044010sg2_p0cc3rec_cl.evt.gz
SXI HK	ah100044010sxi_a0.hk.gz
SXI EVT UF	ah100044010sxi_p0112004e0_uf.evt.gz ah100044010sxi_p0120004e0_uf.evt.gz
SXI MZDYE EVT UF	ah100044010sxi_p0112004e1_uf.evt.gz ah100044010sxi_p0120004e1_uf.evt.gz
SXI HOTPIX	ah100044010sxi_a0112004e0.hpix.gz ah100044010sxi_a0120004e0.hpix.gz
SXI MZDYE HOTPIX	ah100044010sxi_a0112004e1.hpix.gz ah100044010sxi_a0120004e1.hpix.gz
SXI FLICKPIX	ah100044010sxi_a0112004e0.fpix.gz ah100044010sxi_a0120004e0.fpix.gz
SXI MZDYE FLICKPIX	ah100044010sxi_a0112004e1.fpix.gz ah100044010sxi_a0120004e1.fpix.gz
SXI BAD PIXEL IMG	ah100044010sxi_p0112004e0.bimg.gz ah100044010sxi_p0120004e0.bimg.gz
SXI MZDYE BAD PIXEL IMG	ah100044010sxi_p0112004e1.bimg.gz ah100044010sxi_p0120004e1.bimg.gz
SXI TEL	ah100044010sxi_tel.gti.gz

SXI EVT CL	ah100044010sxi_p0112004e0_cl.evt.gz ah100044010sxi_p0120004e0_cl.evt.gz
SXI MZDYE EVT CL	ah100044010sxi_p0112004e1_cl.evt.gz ah100044010sxi_p0120004e1_cl.evt.gz
SXS HK	ah100044010sxs_a0.hk1.gz
SXS ADR	ahsxs_adr.gti.gz
SXS AC EVT	ah100044010sxs_a0ac_uf.evt.gz
SXS PIX12 GAIN	ah100044010sxs_010_px12.ghf.gz
SXS PIX12 EVT	ah100044010sxs_a0px12010_uf.evt.gz
SXS EL GTI	ah100044010sxs_el.gti.gz
SXS TEL	ah100044010sxs_tel.gti.gz
SXS PIX GTI	ah100044010sxs_p0px1010.gti.gz
SXS PIX EXP	ah100044010sxs_p0px1010_exp.gti.gz
SXS PIX UF	ah100044010sxs_p0px1010_uf.evt.gz
SXS PIX CL	ah100044010sxs_p0px1010_cl.evt.gz

a) Untar in a directory `/full/path/to/data/`.

Additional Files

Additional text files for analysis are as follows, and are shown in detail as they are used.

- standard (and other) extraction region files (place in dir `/full/path/to/regions`)
 - `region_SXS_det.reg`
 - `region_HXI_100044010.reg`
 - `region_SXI_100044010.reg`
 - `region_SXI_100044010_bkg.reg`
- HXI lists of gti used for deadtime correction
 - `ah100044010hx1_p0camrecpse_cl.gti.lst`
 - `ah100044010hx2_p0camrecpse_cl.gti.lst`
 - `ah100044010hx1_p0camrec_cl.gti.lst`
 - `ah100044010hx2_p0camrec_cl.gti.lst`

NOTE on source regions files:

- i) 3 arcmin circle (SKY coordinates) for HXI1 and HXI2
- ii) 2.5 arcmin circle (SKY coordinates) for SXI
- iii) Full array (except pixel 12) for SXS (expressed in DET coordinates)

The region centers are determined by estimating the SKY coordinates of the source in the SXI image, and not on the expected source coordinates.

Note on this sequence.

The SGD2 cleaned event files for sequence 100044010 have about an order of magnitude fewer events than the SGD1 cleaned event file due to mkf screening. Only the SGD1 steps are shown here; however, the SGD2 steps may proceed identically.

Non-Instrument Specific Processing

ahcalctime

100044010

(1) Recalculate time for HK and unfiltered event files

```
ahcalctime indir=data/100044010 outdir=data/100044010_ahcalctime_output  
verify_input=no sorttime=yes timecol=TIME clobber=yes  
  
mv *log data/100044010_ahcalctime_output  
cp ~/pfiles/ahcalctime.par data/100044010_ahcalctime_output
```

ahpipeline

(1) Recalibrate and rescreen data for all instruments using ahpipeline

```
ahpipeline indir=data/100044010 outdir=data/100044010_output  
steminputs=ah100044010 stemoutputs=DEFAULT entry_stage=1 exit_stage=2  
instrument=ALL verify_input=no create_ehkmkf=yes seed=7 clobber=yes chatter=2  
mode=hl  
  
mkdir data/100044010_output/logs  
mv *.log data/100044010_output/logs
```

Instrument Specific Reprocessing

100044010

Instrument-specific reprocessing may be applied using ahpipeline by changing the `instrument` parameter from `ALL` to `HX,SGD,SXI`, or `SXS` or by running the individual instrument pipelines as explained in the section 1000500020 (G21.5-0.9).

Extracting Products

This section details tools to run on cleaned event files to get instrument specific data products. These may be applied to the original cleaned event files from the pipeline, or to new cleaned event files created using the steps in the last section. In what follows, the original pipeline cleaned event files are used. The extraction region files described above are assumed to be in the `regions` directory.

100044010

HXI

All newly created output files in this section are placed in the `/full/path/to/data/hxi_products` directory

```
cd /full/path/  
  
mkdir data/products_hxi
```

```
cd data/products_hxi
```

(1) Extract source spectra and light curves using xselect

The content of the region file used here, `.../regions/region_HXI_100044010.reg`, is

```
# Region file format: DS9 version 4.1
fk5
circle(83.6319,22.0188,180") # color=white font="helvetica 30 normal "
```

The HXI data for this sequence is split into two parts, and are combined accordingly below.

HXI1

```
xselect
xsel:SUZAKU > read events
./100044010/hxi/event_cl/ah100044010hx1_p1camrec_cl.evt.gz
xsel:SUZAKU > read events
./100044010/hxi/event_cl/ah100044010hx1_p2camrec_cl.evt.gz
xsel:HIOMI-HXI1-CAMERA_NORMAL2 > extract events
xsel:HIOMI-HXI1-CAMERA_NORMAL2 > save events ah100044010hx1_p0camrec_cl.evt
xsel:HIOMI-HXI1-CAMERA_NORMAL2 > filter region
./././regions/region_HXI_100044010.reg
xsel:HIOMI-HXI1-CAMERA_NORMAL2 > extract spectrum
xsel:HIOMI-HXI1-CAMERA_NORMAL2 > save spectrum ah100044010hx1_p0camrec_cl.pi
xsel:HIOMI-HXI1-CAMERA_NORMAL2 > plot spectrum
xsel:HIOMI-HXI1-CAMERA_NORMAL2 > extract curve
xsel:HIOMI-HXI1-CAMERA_NORMAL2 > save curve ah100044010hx1_p0camrec_cl.lc
xsel:HIOMI-HXI1-CAMERA_NORMAL2 > plot curve
```

HXI2

```
xselect
xsel:SUZAKU > read events
./100044010/hxi/event_cl/ah100044010hx2_p1camrec_cl.evt.gz
xsel:SUZAKU > read events
./100044010/hxi/event_cl/ah100044010hx2_p2camrec_cl.evt.gz
xsel:HIOMI-HXI2-CAMERA_NORMAL2 > extract events
xsel:HIOMI-HXI2-CAMERA_NORMAL2 > save events ah100044010hx2_p0camrec_cl.evt
xsel:HIOMI-HXI2-CAMERA_NORMAL2 > filter region
./././regions/region_HXI_100044010.reg
xsel:HIOMI-HXI2-CAMERA_NORMAL2 > extract spectrum
xsel:HIOMI-HXI2-CAMERA_NORMAL2 > save spectrum ah100044010hx2_p0camrec_cl.pi
xsel:HIOMI-HXI2-CAMERA_NORMAL2 > plot spectrum
xsel:HIOMI-HXI2-CAMERA_NORMAL2 > extract curve
xsel:HIOMI-HXI2-CAMERA_NORMAL2 > save curve ah100044010hx2_p0camrec_cl.lc
xsel:HIOMI-HXI2-CAMERA_NORMAL2 > plot curve
```

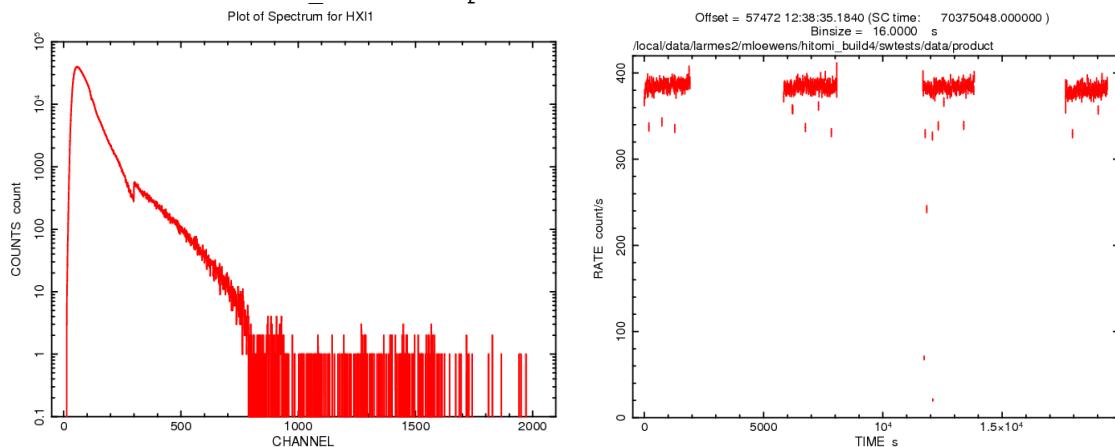


Figure 23: HXI1 source spectrum and lightcurve for sequence 100044010

(2) Construct the dead-time corrected source and background spectra using xselect, hxisgddtime, and ahgtigen

HXI1

(a) Merge the pseudo-event files, including their GTI extensions:

```
ftmerge
"../100044010/hxi/event_cl/ah100044010hx1_p1camrecpse_cl.evt.gz,../100044010/hxi/event_cl/ah100044010hx1_p2camrecpse_cl.evt" ah100044010hx1_p0camrecpse_cl.evt
ahgtigen infile=NONE outfile=ah100044010hx1_p0camrecpse_cl.gti
gtifile=@ah100044010hx1_p0camrecpse_cl.lst gtiexpr=NONE mergegti=OR
```

where ah100044010hx1_p0camrecpse_cl.lst is a text file listing all pseudo event file GTI extensions:

```
../100044010/hxi/event_cl/ah100044010hx1_p1camrecpse_cl.evt.gz+2
../100044010/hxi/event_cl/ah100044010hx1_p2camrecpse_cl.evt.gz+2

ftdelhdu ah100044010hx1_p0camrecpse_cl.evt+2 none confirm=YES

ftappend ah100044010hx1_p0camrecpse_cl.gti+1 ah100044010hx1_p0camrecpse_cl.evt
```

(b) Merge the event file GTI extensions:

```
ahgtigen infile=NONE outfile=ah100044010hx1_p0camrec_cl.gti
gtifile=@ah100044010hx1_p0camrec_cl.lst gtiexpr=NONE mergegti=OR
```

where ah100044010hx1_p0camrec_cl.lst is a text file listing all GTI extensions:

```
../100044010/hxi/event_cl/ah100044010hx1_p1camrec_cl.evt.gz+2
../100044010/hxi/event_cl/ah100044010hx1_p2camrec_cl.evt.gz+2

fthedit ah100044010hx1_p0camrec_cl.gti+1 INSTRUME a HXI1
fthedit ah100044010hx1_p0camrec_cl.gti+1 DETNAM a CAMERA
```

(c) Apply the deadtime correction to the merged source and background spectra and lightcurves, using the merged pseudo-event and event GTI files:

```
hxisgddtime infile=ah100044010hx1_p0camrecpse_cl.evt
inlcfile=ah100044010hx1_p0camrec_cl.lc inspecfile=ah100044010hx1_p0camrec_cl.pi
outlcfile=ah100044010hx1_p1camrec_dtime.lc
outfile=ah100044010hx1_p0camrec_dtime.pi
gtifile=ah100044010hx1_p0camrec_cl.gti

mv hxisgddtime.log hxisgddtime_ah100044010hx1.log
```

HXI2

(a) Merge the pseudo-event files, including their GTI extensions:

```
ftmerge
"../100044010/hxi/event_cl/ah100044010hx2_p1camrecpse_cl.evt.gz,../100044010/hxi/event_cl/ah100044010hx2_p2camrecpse_cl.evt" ah100044010hx2_p0camrecpse_cl.evt
ahgtigen infile=NONE outfile=ah100044010hx2_p0camrecpse_cl.gti
gtifile=@ah100044010hx2_p0camrecpse_cl.lst gtiexpr=NONE mergegti=OR
```

where ah100044010hx2_p0camrecpse_cl.lst is a text file listing all pseudo event file GTI extensions:

```
../100044010/hxi/event_cl/ah100044010hx2_p1camrecpse_cl.evt.gz+2
../100044010/hxi/event_cl/ah100044010hx2_p2camrecpse_cl.evt.gz+2

ftdelhdu ah100044010hx2_p0camrecpse_cl.evt+2 none confirm=YES

ftappend ah100044010hx2_p0camrecpse_cl.gti+1 ah100044010hx2_p0camrecpse_cl.evt
```

(b) Merge the event file GTI extensions:

```
ahgtigen infile=NONE outfile=ah100044010hx2_p0camrec_cl.gti
gtifile=@ah100044010hx2_p0camrec_cl.lst gtiexpr=NONE mergegti=OR
```

where ah100044010hx2_p0camrec_cl.lst is a text file listing all GTI extensions:

```
../100044010/hxi/event_cl/ah100044010hx2_p1camrec_cl.evt.gz+2
../100044010/hxi/event_cl/ah100044010hx2_p2camrec_cl.evt.gz+2

fthedit ah100044010hx2_p0camrec_cl.gti+1 INSTRUME a HXI2
fthedit ah100044010hx2_p0camrec_cl.gti+1 DETNAM a CAMERA
```

(c) Apply the deadtime correction to the merged source and background spectra and lightcurves, using the merged pseudo-event and event GTI files:

```
hxisgddtime infile=ah100044010hx2_p0camrecpse_cl.evt
inlcfile=ah100044010hx2_p0camrec_cl.lc inspecfile=ah100044010hx2_p0camrec_cl.pi
outlcfile=ah100044010hx2_p1camrec_dtime.lc
outfile=ah100044010hx2_p0camrec_dtime.pi
gtifile=ah100044010hx2_p0camrec_cl.gti

mv hxisgddtime.log hxisgddtime_ah100044010hx2.log
```

(3) Apply barycenter corrections for light curves

```
barycen infile=ah100044010hx1_p0camrec_dtime.lc
outfile=ah100044010hx1_p0camrec_dtime_add_bary.lc
orbfile=../100044010/auxil/ah100044010.orb.gz ra=83.633 dec=22.0145
orbext=ORBIT chatter=2 clobber=yes

mv barycen.log barycen_ah100044010hx1.log

barycen infile=data/products_hxi/ah100044010hx2_p0camrec_dtime.lc
outfile=data/products_hxi/ah100044010hx2_p0camrec_dtime_add_bary.lc
orbfile=data/100044010/auxil/ah100044010.orb.gz ra=83.633 dec=22.0145
orbext=ORBIT chatter=2 clobber=yes

mv barycen.log barycen_ah100044010hx2.log
```

Note that the `ra` and `dec` parameters are set here to the object coordinates as an approximation of the true average pointing direction; this setting can be refined by generating and examining the exposure map (see below).

The barycenter correction may also be applied to event files.

SGD

All newly created output files in this section are placed in the `/full/path/to/data/sgd_products` directory

```

cd /full/path/
mkdir data/products_sgd
cd data/products_sgd

```

(1) Extract source spectrum and light curves, summed over all Compton cameras, using xselect

SGD1

```

xselect
xsel:SUZAKU > read events
..../100044010/sgd/event_cl/ah100044010sg1_p0cc1rec_cl.evt.gz
xsel:HIOTMI-SGD1-CC_NORMAL1 > read events
..../100044010/sgd/event_cl/ah100044010sg1_p0cc2rec_cl.evt.gz
xsel:HIOTMI-SGD1-CC_NORMAL1 > read events
..../100044010/sgd/event_cl/ah100044010sg1_p0cc3rec_cl.evt.gz
xsel:HIOTMI-SGD1-CC_NORMAL1 > extract events
xsel:HIOTMI-SGD1-CC_NORMAL1 > save events ah100044010sg1_p0ccALLrec_cl.evt
xsel:HIOTMI-SGD1-CC_NORMAL1 > extract spectrum
xsel:HIOTMI-SGD1-CC_NORMAL1 > plot spectrum
xsel:HIOTMI-SGD1-CC_NORMAL1 > save spectrum ah100044010sg1_p0ccALLrec_cl.pi
xsel:HIOTMI-SGD1-CC_NORMAL1 > extract curve
xsel:HIOTMI-SGD1-CC_NORMAL1 > plot curve
xsel:HIOTMI-SGD1-CC_NORMAL1 > save curve ah100044010sg1_p0ccALLrec_cl.lc

```

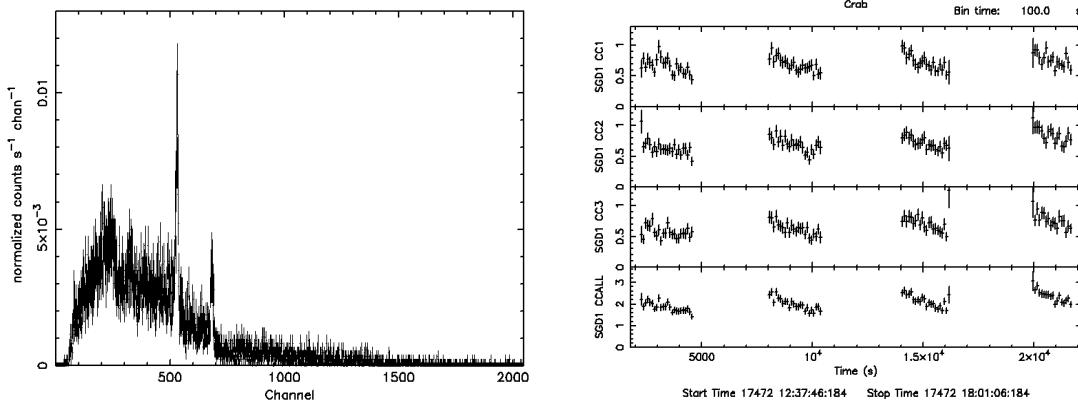


Figure 24: SGD1 source spectrum (left) and lightcurve (right) for sequence 100044010 plotted using XSPEC and XRONOS (lcurve).

(2) Run hxisgddtime to correct the spectrum and light curve for dead time

SGD1

First, extract the spectrum and light curve for each individual camera.

```

xselect
xsel:SUZAKU > read events
..../100044010/sgd/event_cl/ah100044010sg1_p0cc1rec_cl.evt.gz
xsel:HIOTMI-SGD1-CC_NORMAL1 > extract spectrum
xsel:HIOTMI-SGD1-CC_NORMAL1 > save spectrum ah100044010sg1_p0cc1rec_cl.pi
xsel:HIOTMI-SGD1-CC_NORMAL1 > extract curve
xsel:HIOTMI-SGD1-CC_NORMAL1 > save curve ah100044010sg1_p0cc1rec_cl.lc
xsel:HIOTMI-SGD1-CC_NORMAL1 > clear all
xsel:HIOTMI-SGD1-CC_NORMAL1 > read events
..../100044010/sgd/event_cl/ah100044010sg1_p0cc2rec_cl.evt.gz
xsel:HIOTMI-SGD1-CC_NORMAL1 > extract spectrum

```

```

xsel: HITOMI-SGD1-CC_NORMAL1 > save spectrum ah100044010sg1_p0cc2rec_cl.pi
xsel: HITOMI-SGD1-CC_NORMAL1 > extract curve
xsel: HITOMI-SGD1-CC_NORMAL1 > save curve ah100044010sg1_p0cc2rec_cl.lc
xsel: HITOMI-SGD1-CC_NORMAL1 > clear all
xsel: HITOMI-SGD1-CC_NORMAL1 > read events
./100044010/sgd/event_cl/ah100044010sg1_p0cc3rec_cl.evt.gz
xsel: HITOMI-SGD1-CC_NORMAL1 > extract spectrum
xsel: HITOMI-SGD1-CC_NORMAL1 > save spectrum ah100044010sg1_p0cc3rec_cl.pi
xsel: HITOMI-SGD1-CC_NORMAL1 > extract
xsel: HITOMI-SGD1-CC_NORMAL1 > save curve ah100044010sg1_p0cc3rec_cl.lc

```

Apply the deadtime correction to each camera

```

hxisgddtime
infile=../100044010/sgd/event_cl/ah100044010sg1_p0cc1recpse_cl.evt.gz
inlcfile=ah100044010sg1_p0cc1rec_cl.lc inspecfile=ah100044010sg1_p0cc1rec_cl.pi
outlcfile=ah100044010sg1_p0cc1rec_dtime.lc
outfile=ah100044010sg1_p0cc1rec_dtime.pi
gtifile=../100044010/sgd/event_cl/ah100044010sg1_p0cc1rec_cl.evt.gz chatter=2
clobber=yes

```

```
mv hxisgddtime.log hxisgddtime_ah100044010sg1cc1.log
```

```

hxisgddtime
infile=../100044010/sgd/event_cl/ah100044010sg1_p0cc2recpse_cl.evt.gz
inlcfile=ah100044010sg1_p0cc2rec_cl.lc inspecfile=ah100044010sg1_p0cc2rec_cl.pi
outlcfile=ah100044010sg1_p0cc2rec_dtime.lc
outfile=ah100044010sg1_p0cc2rec_dtime.pi
gtifile=../100044010/sgd/event_cl/ah100044010sg1_p0cc2rec_cl.evt.gz chatter=2
clobber=yes

```

```
mv hxisgddtime.log hxisgddtime_ah100044010sg1cc2.log
```

```

hxisgddtime
infile=../100044010/sgd/event_cl/ah100044010sg1_p0cc3recpse_cl.evt.gz
inlcfile=ah100044010sg1_p0cc3rec_cl.lc inspecfile=ah100044010sg1_p0cc3rec_cl.pi
outlcfile=ah100044010sg1_p0cc3rec_dtime.lc
outfile=ah100044010sg1_p0cc3rec_dtime.pi
gtifile=../100044010/sgd/event_cl/ah100044010sg1_p0cc3rec_cl.evt.gz chatter=2
clobber=yes

```

```
mv hxisgddtime.log hxisgddtime_ah100044010sg1cc3.log
```

Add the individual spectra, and add the keywords needed by *sgdarfgen* read from the header of any of the individual spectra (identified using *fkeyprint*), and with the EXPOSURE set to the average of the three individual spectra.

```

mathpha
expr=ah100044010sg1_p0cc1rec_dtime.pi+ah100044010sg1_p0cc2rec_dtime.pi+ah100044010sg1_p0cc3rec_dtime.pi units=C outfil=ah100044010sg1_p0ccALLrec_dtime.pi
exposure=4871 areascal=% backscal=% ncomments=0

fthedit ah100044010sg1_p0ccALLrec_dtime.pi+1 RA_NOM a 83.6348495483012
fthedit ah100044010sg1_p0ccALLrec_dtime.pi+1 DEC_NOM a 22.0146021574681
fthedit ah100044010sg1_p0ccALLrec_dtime.pi+1 PA_NOM a 267.721269104422
fthedit ah100044010sg1_p0ccALLrec_dtime.pi+1 DATE-OBS a 2016-03-25T12:35:48

```

SXI

All newly created output files in this section are placed in the /full/path/to/data/sxi_products directory

```
cd /full/path/
```

```
mkdir data/products_sxi  
cd data/products_sxi
```

There are two cleaned SXI event files for sequence 100044010:

```
../100044010/sxi/event_cl/ah100044010sxi_p0112004e0_cl.evt.gz  
../100044010/sxi/event_cl/ah100044010sxi_p0112004e1_cl.evt.gz
```

The files ending in “1”, i.e. “p0112004e1”, refer to “Minus-Z Day Earth” (MZDYE) data conducted with area discrimination on and different event thresholds. These must be independently analyzed from the files ending in “0” or “Normal” data files. Here list the steps for the Normal mode data; the section 1000500020 (G21.5-0.9) for an example of the steps for MZDYE mode.

The content of the source region file used here, `.../regions/region_SXI_100044010.reg`, which excludes the central 30 arcsec to reduce pileup effects, is

```
# Region file format: DS9 version 4.1  
fk5  
circle(83.6319,22.0188,150") # color=white font="helvetica 30 normal "
```

(1) Extract image, spectrum, and light curve using xselect

```
xselect  
xsel:SUZAKU > read events  
./100044010/sxi/event_cl/ah100044010sxi_p0112004e0_cl.evt.gz  
xsel:HITOMI-SXI-WINDOW1 > filter pha_cutoff 83 1333  
xsel:HITOMI-SXI-WINDOW1 > set xybin 4  
xsel:HITOMI-SXI-WINDOW1 > extract image  
xsel:HITOMI-SXI-WINDOW1 > save image ah100044010sxi_p0112004e0_cl.img  
xsel:HITOMI-SXI-WINDOW1 > plot image  
xsel:HITOMI-SXI-WINDOW1 > clear pha_cutoff  
xsel:HITOMI-SXI-WINDOW1 > filter region .../regions/region_SXI_100044010.reg  
xsel:HITOMI-SXI-WINDOW1 > extract spectrum  
xsel:HITOMI-SXI-WINDOW1 > save spectrum ah100044010sxi_p0112004e0_cl.pi  
xsel:HITOMI-SXI-WINDOW1 > plot spectrum  
xsel:HITOMI-SXI-WINDOW1 > extract curve exposure=0.0  
xsel:HITOMI-SXI-WINDOW1 > save curve ah100044010sxi_p0112004e0_cl.lc  
xsel:HITOMI-SXI-WINDOW1 > plot curve
```

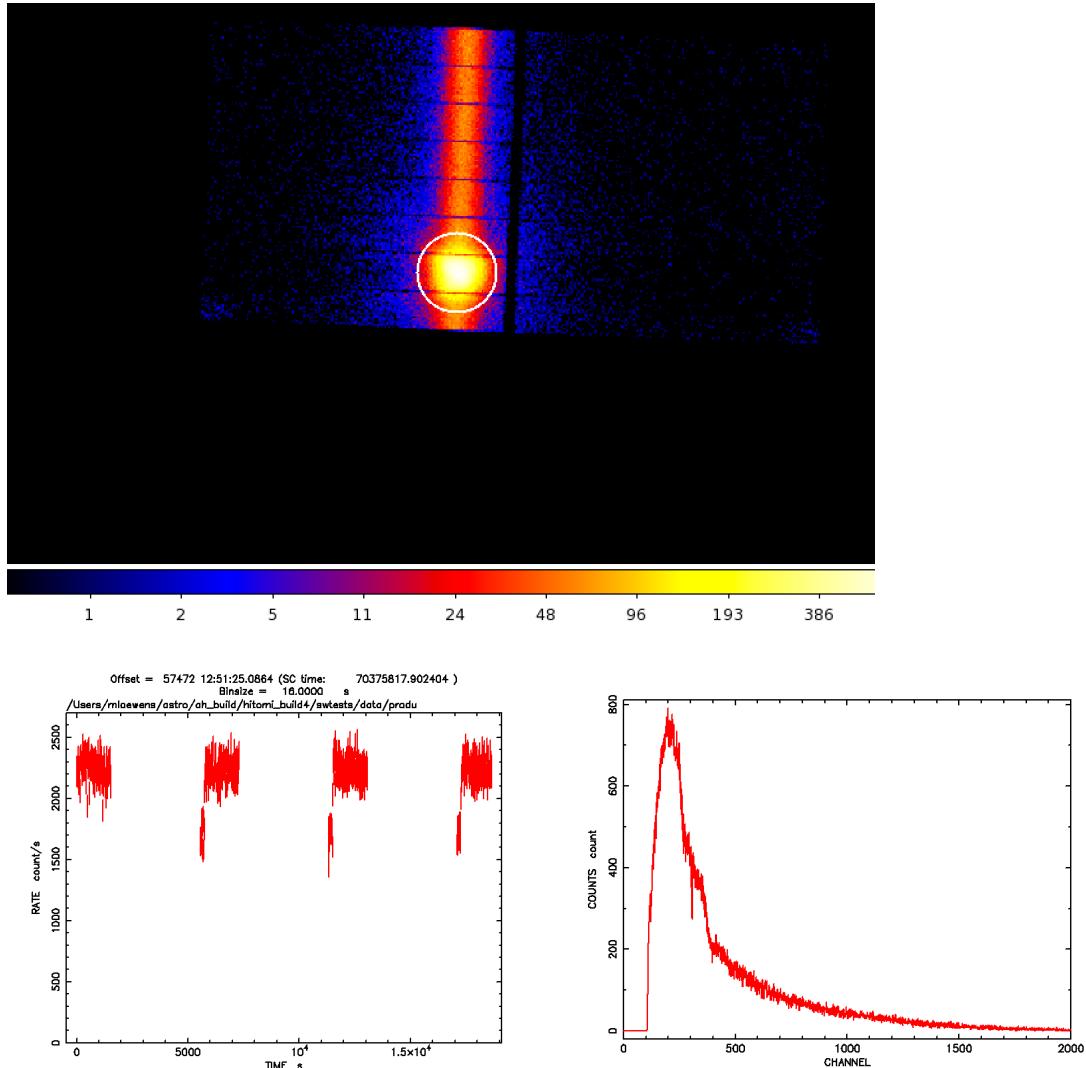


Figure 25: SXI images (with extraction region), source lightcurve, and spectrum for sequence 100044010.

SXS

All newly created output files in this section are placed in the /full/path/to/data/sxs_products directory

```
cd /full/path/
mkdir data/products_sxs
cd data/products_sxs
```

(1) Additional screening

Create a “cleaned-2” SXS event file

```
ah100044010sxs_p0px1010_c12.evt
```

by applying a RISETIME cut to Hp, Mp, Ms, and Lp (but not Ls) events.

```

ftselect
infile='..../100044010/sxs/event_cl/ah100044010sxs_p0px1010_cl.evt.gz[events]'
outfile=ah100044010sxs_p0px1010_cl2.evt expression="(PI>=400)&&((RISE_TIME>=40
& RISE_TIME<=60 && ITYPE<4) || (ITYPE==4))"

```

Note that the current pipeline screening already excludes events with PI<600.

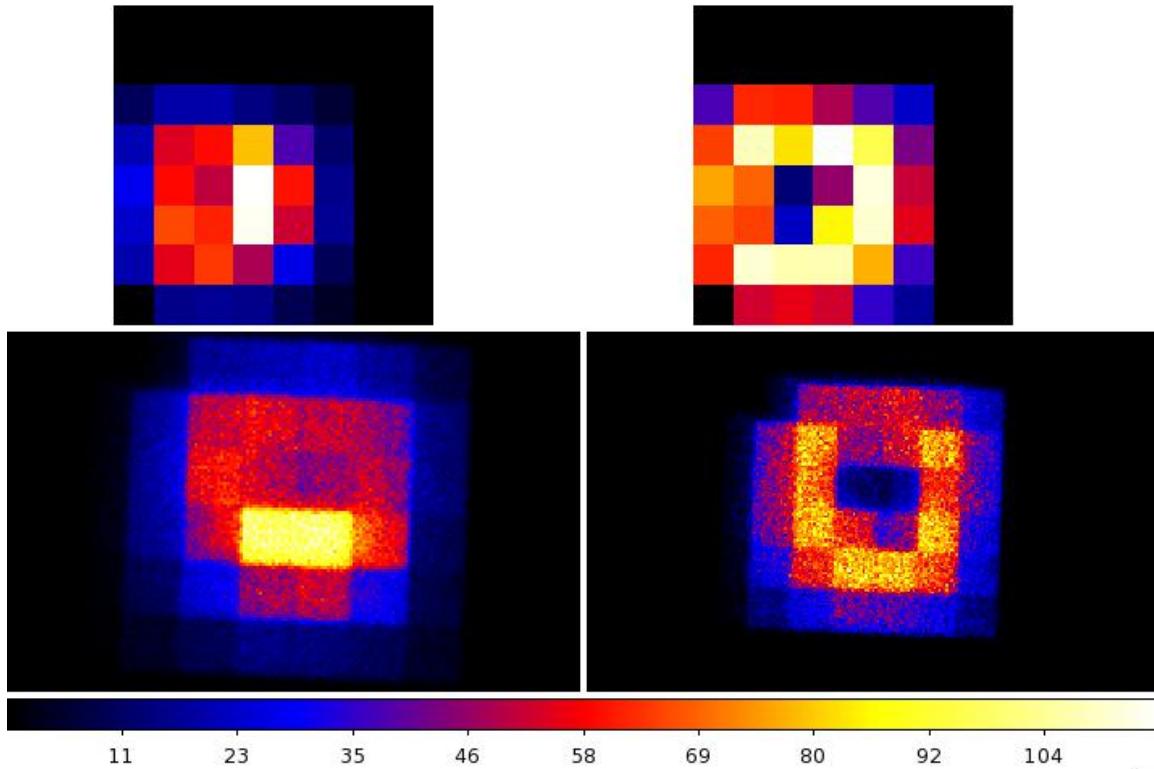
(2) Extract source spectra and light curves using xselect

```

xsel:SUZAKU > read events ah100044010sxs_p0px1010_cl2.evt
xsel:HITOMI-SXS-PX_NORMAL > filter column "PIXEL=0:11,13:35"
xsel:HITOMI-SXS-PX_NORMAL > extract image
xsel:HITOMI-SXS-PX_NORMAL > save image ah100044010sxs_p0px1010_cl2_sky.img
xsel:HITOMI-SXS-PX_NORMAL > set xname detx dy
xsel:HITOMI-SXS-PX_NORMAL > extract image
xsel:HITOMI-SXS-PX_NORMAL > save image ah100044010sxs_p0px1010_cl2_det.img
xsel:HITOMI-SXS-PX_NORMAL > extract curve exposure=0
xsel:HITOMI-SXS-PX_NORMAL > save curve ah100044010sxs_p0px1010_cl2_lc
xsel:HITOMI-SXS-PX_NORMAL > filter GRADE "0:1"
xsel:HITOMI-SXS-PX_NORMAL > set xname x y
xsel:HITOMI-SXS-PX_NORMAL > extract image
xsel:HITOMI-SXS-PX_NORMAL > save image ah100044010sxs_p0px1010_cl2_HMPM_sky.img
xsel:HITOMI-SXS-PX_NORMAL > set xname detx dy
xsel:HITOMI-SXS-PX_NORMAL > extract image
xsel:HITOMI-SXS-PX_NORMAL > save image ah100044010sxs_p0px1010_cl2_HMPM_det.img
xsel:HITOMI-SXS-PX_NORMAL > extract curve exposure=0
xsel:HITOMI-SXS-PX_NORMAL > save curve ah100044010sxs_p0px1010_cl2_HMPM_lc
xsel:HITOMI-SXS-PX_NORMAL > extract spectrum
xsel:HITOMI-SXS-PX_NORMAL > save spectrum ah100044010sxs_p0px1010_cl2_HMPM.pi

```

Note that Pixel 12 events may already be excluded from the cleaned event files depending on the label used in filtering; in those cases the second step above may be skipped.



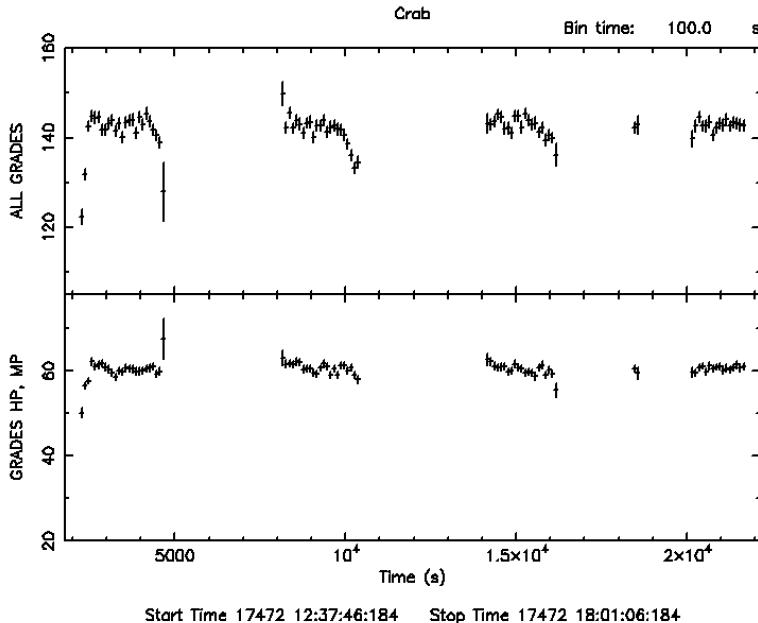


Figure 26: SXS images and lightcurves (plotted using XRONOS/lcurve) for sequence 100044010 for all grades (left images, top lightcurve) and grades HP/MP (right images, bottom light curve).

Generating Exposure Map, RMF, and ARF

100044010

HXI

All newly created output files in this section are placed in the /full/path/to/data/hxi_products directory

```
cd /full/path/
cd data/products_hxi
```

(1) Create an exposure map for each HXI

The exposure maps generated here are used in the two examples below to make both the RSP and flat field for the HXI. Note: The exposure maps are created with the parameters `delta=20.0`, `numphi=1` to assure that the map includes only a single attitude bin, i.e. assuming that the attitude is stable relative to the size of the PSF and extraction region.

HXI1

```
ahexpmap ehkfile=../100044010/auxil/ah100044010.ehk.gz
gtifile=ah100044010hx1_p0camrec_cl.evt instrume=HXI1 badimgfile=None
pixgtifile=None outfile=ah100044010hx1_p0camrec.expo outmaptype=EXPOSURE
delta=20.0 numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB
vigfile=CALDB obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes
fwtype=DEFAULT specmode=MONO specfile=spec.fits specform=FITS energy=10.0
evperchan=DEFAULT abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100044010hx1_p0camrec.log
```

HXI2

```
ahexpmap ehkfile=../100044010/auxil/ah100044010.ehk.gz
gtifile=ah100044010hx2_p0camrec_cl.evt instrume=HXI2 badimgfile=None
pixgtifile=None outfile=ah100044010hx2_p0camrec.expo outmaptype=EXPOSURE
delta=20.0 numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB
vigfile=CALDB obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes
fwtype=DEFAULT specmode=MONO specfile=spec.fits specform=FITS energy=10.0
evperchan=DEFAULT abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100044010hx2_p0camrec.log
```

(2) Create an RSP for each HXI

Make RSP for HXI1 and HXI2, sampling=120, point source at center of extraction region region_HXI_100044010.reg. In general, the source_ra and source_dec parameters should be the coordinates of the center of the source in the image, which are not necessarily the same as the actual source coordinates. Here we use the center of the spectral extraction region. An on-axis point source response can be constructed by setting the source coordinates to the single value of RANOMXP and DECNOMXP in the first extension of the exposure map. The runtime estimated above is for the case above where the exposure map has a single attitude bin. The parameter numphoton may need to be decreased to accommodate a larger number of attitude bins.

HXI1

```
aharfgen xrtevtfile=raytrace_ah100044010hx1_p0camrec.fits source_ra=83.6319
source_dec=22.0188 telescop=HITOMI instrume=HXI1
emapfile=ah100044010hx1_p0camrec.expo
dattfile=../100044010/hxi/event_uf/ah100044010hx1.att.gz regmode=SKY
regionfile=../../regions/region_HXI_100044010.reg sampling=120 sourcetype=point
erange="4.0 80.0" outfile=ah100044010hx1_rt
filtoffsetfile=../100044010/hxi/event_uf/ah100044010hx1_cms.fits.gz
numphoton=10000 minphoton=1 teldeffile=CALDB qefile=CALDB rmffile=CALDB
onaxisffile=CALDB onaxiscfle=CALDB mirrorfile=CALDB obstructfile=CALDB
frontreffile=CALDB pcolreffile=CALDB scatterfile=CALDB seed=7 clobber=yes
chatter=2 mode=h logfile=make_arf_ah100044010hx1_p0camrec.log
```

HXI2

```
aharfgen xrtevtfile=raytrace_ah100044010hx2_p0camrec.fits source_ra=83.6319
source_dec=22.0188 telescop=HITOMI instrume=HXI2
emapfile=ah100044010hx2_p0camrec.expo
dattfile=../100044010/hxi/event_uf/ah100044010hx2.att.gz regmode=SKY
regionfile=../../regions/region_HXI_100044010.reg sampling=120 sourcetype=point
erange="4.0 80.0" outfile=ah100044010hx2_rt
filtoffsetfile=../100044010/hxi/event_uf/ah100044010hx2_cms.fits.gz
numphoton=10000 minphoton=1 teldeffile=CALDB qefile=CALDB rmffile=CALDB
onaxisffile=CALDB onaxiscfle=CALDB mirrorfile=CALDB obstructfile=CALDB
frontreffile=CALDB pcolreffile=CALDB scatterfile=CALDB seed=7 clobber=yes
chatter=2 mode=h logfile=make_arf_ah100044010hx2_p0camrec.log
```

(3) Create flat field efficiency images for each HXI

HXI1

```
hxirspeffimg telescop=HITOMI instrume=HXI1
emapfile=ah100044010hx1_p0camrec.expo
xrtevtfile=raytrace_ah100044010hx1_p0camrec.fits onaxisffile=CALDB
onaxiscfle=CALDB regionfile=None
dattfile=../100044010/hxi/event_uf/ah100044010hx1.att.gz stopsys=SKY
```

```

sampling=40 erange="4.0 80.0"
filtoffsetfile=../100044010/hxi/event_uf/ah100044010hx1_cms.fits.gz
outflatfile=ah100044010hx1_flatfield.fits vigfile=CALDB outmaptype=EFFICIENCY
gefille=CALDB rmffile=CALDB clobber=yes chatter=2 mode=h
logfile=make_flat_ah100044010hx1_p0camrec.log

```

HXI2

```

hxirspeffimg telescop=HITOMI instrume=HXI2
emapfile=ah100044010hx2_p0camrec.expo
xrtevtfile=raytrace_ah100044010hx2_p0camrec.fits onaxisffile=CALDB
onaxiscfile=CALDB regionfile=NONE
dattfile=../100044010/hxi/event_uf/ah100044010hx2.att.gz stopsys=SKY
sampling=40 erange="4.0 80.0"
filtoffsetfile=../100044010/hxi/event_uf/ah100044010hx2_cms.fits.gz
outflatfile=ah100044010hx2_flatfield.fits vigfile=CALDB outmaptype=EFFICIENCY
gefille=CALDB rmffile=CALDB clobber=yes chatter=2 mode=h
logfile=make_flat_ah100044010hx2_p0camrec.log

```

These commands produce the images shown below:

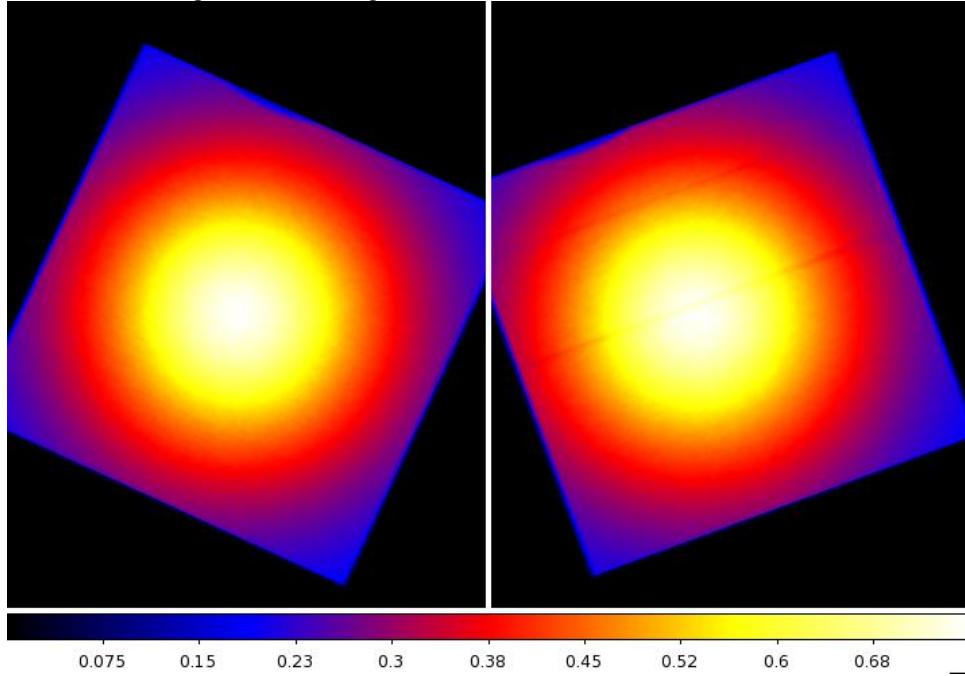


Figure 27: HXI1 (left) and HXI2 (right) flat field images for sequence 100044010.

SGD

All newly created output files in this section are placed in the /full/path/to/data/hxi_products directory

```
cd /full/path/
```

```
cd data/products_sgd
```

All newly created output files in this section are placed in the /full/path/to/data/sgd_products directory

Create the individual response files for each SGD1 Compton camera, and co-add them. To construct an on-axis response, directly co-add the CALDB response files used as input to the SGD arf generator. Here we use the center of the HXI/SXI spectral extraction region as the source coordinates.

SGD1

```
sgdarfgen infile=ah100044010sg1_p0ccALLrec_dtime.pi
rspfile="$CALDB/data/hitomi/sgd/cpf/response/ah_sg1_cc1_20140101v001.rsp,$CALDB
/data/hitomi/sgd/cpf/response/ah_sg1_cc2_20140101v001.rsp,$CALDB/data/hitomi/sg
d/cpf/response/ah_sg1_cc3_20140101v001.rsp" outfile=outrsp_100044010 ra=83.6319
dec=22.0188 sgdid=1 ccid=0 clobber=yes

addrmf
outrsp_100044010_sg1_cc1.rsp,outrsp_100044010_sg1_cc2.rsp,outrsp_100044010_sg
d1_cc3.rsp 1.0,1.0,1.0 ah100044010_sg1_ccALL.rsp
```

SXI

All newly created output files in this section are placed in the /full/path/to/data/sxi_products directory

```
cd /full/path/
cd data/products_sxi
```

(1) Create an RMF for the source spectrum

```
sxirmf infile=ah100044010sxi_p0112004e0_cl.pi
outfile=ah100044010sxi_p0112004e0_cl.rmf clobber=yes mode=h1
```

(2) Create an Exposure Map for the source spectrum

The exposure map, and flatfield image below, are created with the parameters `delta=20.0`, `numphi=1` to assure that the map includes only a single attitude bin, i.e. assuming that the attitude is stable relative to the size of the PSF and extraction region.

```
ahexpmap ehkfile=../100044010/auxil/ah100044010.ehk.gz
gtifile=../100044010/sxi/event_cl/ah100044010sxi_p0112004e0_cl.evt.gz
instrume=SXI
badimgfile=../100044010/sxi/event_uf/ah100044010sxi_p0112004e0.bimg.gz
pixgtifile=../100044010/sxi/event_uf/ah100044010sxi_a0112004e0.fpix.gz
outfile=ah100044010sxi_p0112004e0.expo outmaptyle=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100044010sxi_a0112004e0.log
```

(3) Create an ARF for the source spectrum (~25 min)

In general, the `source_ra` and `source_dec` parameters should be the coordinates of the center of the source in the image, which are not necessarily the same as the actual source coordinates. The runtime estimated above is for the case above where the exposure map has a single attitude bin. The parameter `numphoton` may need to be decreased to accommodate a larger number of attitude bins. Because of the smaller region, `numphoton` is increased from 300000 to 3000000.

```
aharfgen xrtevtfile=raytrace_ah100044010sxi_p0112004e0_ptsrc_evt.fits
source_ra=83.6319 source_dec=22.0188 telescop=HITOMI instrume=SXI
emapfile=ah100044010sxi_p0112004e0.expo regmode=SKY
regionfile=../../regions/region_SXI_100044010.reg sourcetype=POINT
rmffile=ah100044010sxi_p0112004e0_cl.rmf erange="0.5 16.0 0 0"
outfile=ah100044010sxi_p0112004e0_rt.arf numphoton=3000000 minphoton=1
teldeffile=CALDB qefile=CALDB contamofile=CALDB onaxisffile=CALDB
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
```

```
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB seed=7 clobber=yes
chatter=2 mode=h logfile=make_arf_ah100044010sxi_p0112004e0.log
```

(4) Create an efficiency map (flat field)

```
ahexpmap ehkfile=../100044010/auxil/ah100044010.ehk.gz
gtifile=ah100044010sxi_p0112004e0_cl.evt instrume=SXI
badimgfile=../100044010/sxi/event_uf/ah100044010sxi_p0112004e0.bimg.gz
pixgtifile=../100044010/sxi/event_uf/ah100044010sxi_a0112004e0.fpix.gz
outfile=ah100044010sxi_p0112004e0.flat outmapttype=EFFICIENCY delta=20.0
numphi=1 stopsyst=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_flat_ah100044010sxi_a0112004e0.log
```

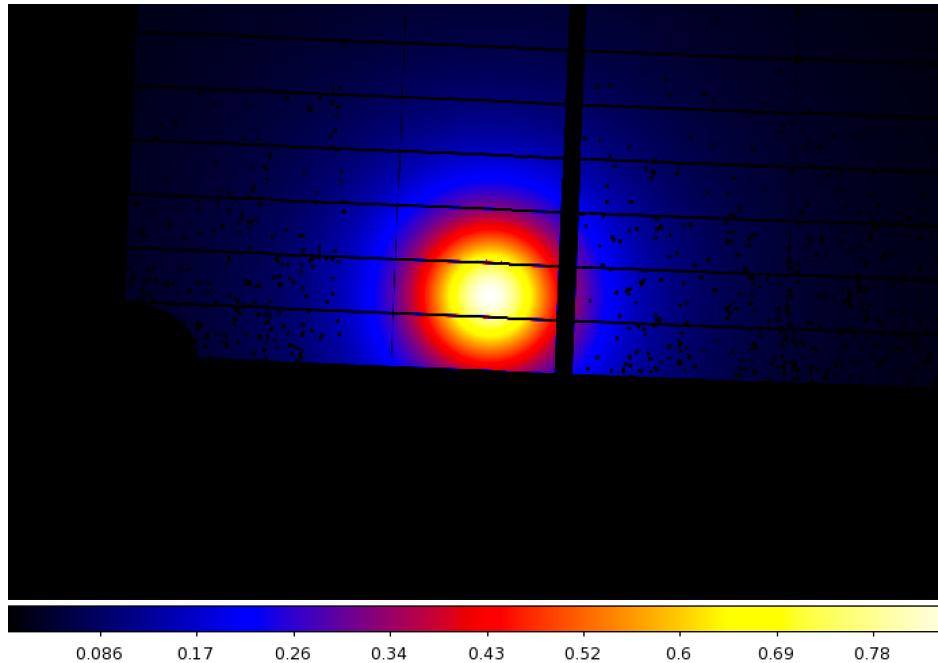


Figure 28: SXI flat field images for sequence 100044010.

SXS

All newly created output files in this section are placed in the /full/path/to/data/sxs_products directory

```
cd /full/path/
```

```
cd data/products_sxs
```

(1) Generate the RMF

Here we use the “small” size option (Gaussian core only). Change whichrmf parameter to “m” to include exponential tail to low energies, and to “l” to include escape peaks. The all-pixel DET coordinate region file ah100044010sxs_region_SXS_det.reg, identical to the generic region file region_sxs_det.reg. that may be created by sxsregext is input:

```
physical
```

```

+box(4,1,5,1.0000000)
+box(3.5,2,6,1.0000000)
+box(3.5,3,6,1.0000000)
+box(3.5,4,6,1.0000000)
+box(3.5,5,6,1.0000000)
+box(3.5,6,6,1.0000000)

sxsmkrmf infile=ah100044010sxs_p0px1010_c12.evt
outfile=ah100044010_sxs_c12_HMPM_small.rmf resolist=0,1 regmode=det
regionfile=../../regions/ah100044010sxs_region_SXS_det.reg whichrmf=s

```

We also construct an SXS RMF using the “x-large” option which is necessary to study the spectrum below 2 keV.

```

sxsmkrmf infile=ah100044010sxs_p0px1010_c12.evt
outfile=ah100044010_sxs_c12_HMPM_xlarge.rmf resolist=0,1 regmode=det
regionfile=../../regions/ah100044010sxs_region_SXS_det.reg whichrmf=x

```

(2) Generate the SXS exposure maps

Note: The exposure maps created with sxsregext are replaced using the parameters delta=20.0, numphi=1 to assure that map includes only a single attitude bin. This assumes that the attitude is stable relative to the size of the PSF and extraction region. We also account for the lost event gti per pixel here by inputting the pixgti file ah100044010sxs_px1010_exp.gti and setting the pixgtifile parameter accordingly -- this should be done if the lost event gti are not used in the screening (as in the standard pipeline).

```

ahexpmap ehkfile=../100044010/auxil/ah100044010.ehk.gz
gtifile=ah100044010sxs_p0px1010_c12.evt instrume=SXS badimgfile=NONE
pixgtifile=../100044010/sxs/event_uf/ah100044010sxs_px1010_exp.gti.gz
outfile=ah100044010sxs_p0px1010.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamofile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100044010sxs_p0px1010.log

```

3) Generate the SXS ARF

The runtime estimated above is for the case above where the exposure map has a single attitude bin. The parameter numphoton may need to be decreased to accommodate larger number of attitude bins. Here we use the center of the SXI spectral extraction region as the source coordinates.

```

aharfgen xrtevtfle=raytrace_ah100044010sxs_p0px1010.fits source_ra=83.6319
source_dec=22.0188 telescop=HITOMI instrume=SXS
emapfile=ah100044010sxs_p0px1010.expo regmode=DET
regionfile=../../regions/ah100044010sxs_region_SXS_det.reg sourcetype=POINT
rmffile=ah100044010_sxs_c12_HMPM_small.rmf erange="0.5 17.0 0 0"
outfile=ah100044010sxs_p0px1010_rt.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamofile=CALDB obffile=CALDB fwfile=CALDB
gatevalvefile=CALDB onaxisffile=CALDB onaxiscfle=CALDB mirrorfile=CALDB
obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB
scatterfile=CALDB seed=7 clobber=yes chatter=2 mode=h
logfile=make_arf_ah100044010sxs_p0px1010.log

```

Note that the source_ra and source_dec are taken from the region file region_SXI_100044010.reg, i.e. an estimate of the source coordinates based on the SXI image. The region file used is the one in DET coordinates created above by sxsregext.

Spectral Fitting

Notes

The following XSPEC settings are used below.

For fitting;

```
abund wilm  
xsect vern  
statistic cstat
```

For plotting:

```
setplot rebin 10 20 (HXI, SGD, SXI)  
setplot rebin 20 40 (SXS)
```

HXI

(1) Jointly fit the HXI1 and HXI2 deadtime-corrected spectra in the 5-40 keV band with a power-law model, with absorption fixed at $3.0 \times 10^{21} \text{ cm}^{-2}$ using the RSP files created in the previous section. Background is not subtracted in this example.

```
2 files 2 spectra  
Spectrum 1 Spectral Data File: ah100044010hx1_p0camrec_dtime.pi  
Net count rate (cts/s) for Spectrum:1 4.041e+02 +/- 2.613e-01  
Assigned to Data Group 1 and Plot Group 1  
Noticed Channels: 51-399  
Telescope: HITOMI Instrument: HXI1 Channel Type: PI  
Exposure Time: 5918 sec  
Using fit statistic: cstat  
Using test statistic: chi  
Using Response (RMF) File ah100044010hx1_rt.rsp for Source 1  
  
Spectral data counts: 2.39121e+06  
Model predicted rate: 404.091  
  
Spectrum 2 Spectral Data File: ah100044010hx2_p0camrec_dtime.pi  
Net count rate (cts/s) for Spectrum:2 3.556e+02 +/- 2.406e-01  
Assigned to Data Group 2 and Plot Group 2  
Noticed Channels: 51-399  
Telescope: HITOMI Instrument: HXI2 Channel Type: PI  
Exposure Time: 6141 sec  
Using fit statistic: cstat  
Using test statistic: chi  
Using Response (RMF) File ah100044010hx2_rt.rsp for Source 1  
  
Spectral data counts: 2.18368e+06  
Model predicted rate: 355.591
```

Current model list:

```
=====  
Model TBabs<1>*pegpwrlw<2> Source No.: 1 Active/On  
Model Model Component Parameter Unit Value  
par comp  
Data group: 1  
1 1 TBabs nH 10^22 0.300000 frozen  
2 2 pegpwrlw PhoIndex 2.14403 +/- 1.56743E-03  
3 2 pegpwrlw eMin keV 2.00000 frozen
```

```

4    2    pegpwrlw   eMax      keV      10.0000    frozen
5    2    pegpwrlw   norm          2.26241E+04 +/- 30.2876
                                         Data group: 2
6    1    TBabs      nH        10^22     0.300000    frozen
7    2    pegpwrlw   PhoIndex      2.17860    +/- 1.62954E-03
8    2    pegpwrlw   eMin      keV      2.00000    frozen
9    2    pegpwrlw   eMax      keV      10.0000    frozen
10   2    pegpwrlw  norm          2.10133E+04 +/- 29.6570

```

Using energies from responses.

Fit statistic : C-Statistic = 1793.39 using 698 PHA bins and 694 degrees of freedom.

Test statistic : Chi-Squared = 1803.57 using 698 PHA bins.
 Reduced chi-squared = 2.59880 for 694 degrees of freedom
 Null hypothesis probability = 1.294526e-99
 Weighting method: standard

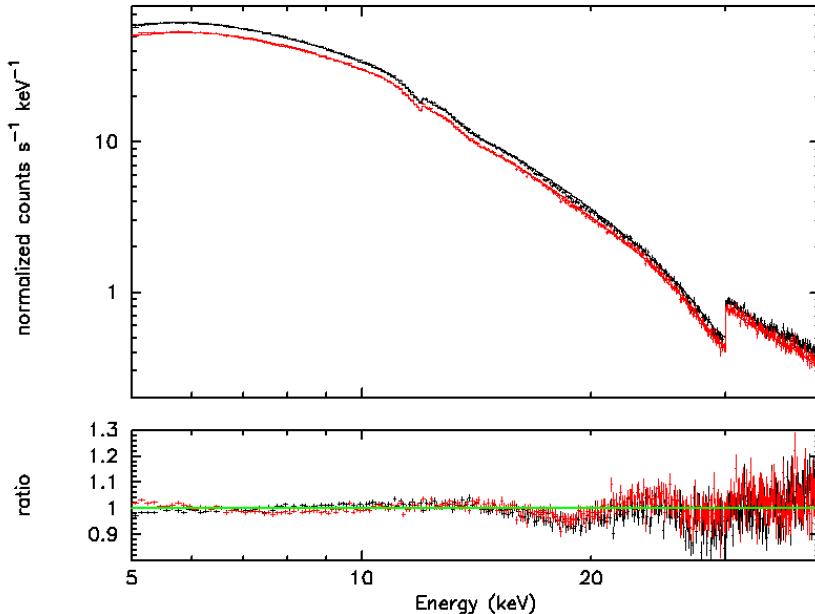


Figure 29: Joint fits to HXI1 (black) and HXI2 (red) spectra for Crab nebula sequence 100044010. The 2-10 keV unabsorbed fluxes are 2.26 (HXI1) and 2.10 (HXI2) $\times 10^{-8}$ erg cm $^{-2}$ s $^{-1}$ in the best-fit models.

SGD

(1) Compare the deadtime-corrected and the deadtime-uncorrected SGD1 spectra (summed over all relevant sequences and all Compton cameras) with the estimated CALDB NXB spectrum
`$CALDB/data/hitomi/sgd/cpf/background/ah_sgd_nxb_20140101v001.pha:`

```

3 files 3 spectra
Spectrum 1 Spectral Data File: ah_sgd_nxb_20140101v001.pha
Net count rate (cts/s) for Spectrum:1 7.661e-01 +/- 1.153e-03
Assigned to Data Group 1 and Plot Group 1
Noticed Channels: 42-2048
Telescope: HITOMI Instrument: SGD Channel Type: PI
Exposure Time: 5.763e+05 sec
Using fit statistic: cstat

```

```

Using test statistic: chi
Using Response (RMF) File ah100044010_sgd1_ccALL.rsp for Source 1

Spectral data counts: 441486
Model predicted rate: 0.0

Spectrum 2 Spectral Data File: ah100044010sg1_p0ccALLrec_c1.pi
Net count rate (cts/s) for Spectrum:2 2.053e+00 +/- 1.543e-02
Assigned to Data Group 2 and Plot Group 2
Noticed Channels: 42-2048
Telescope: HITOMI Instrument: SGD1 Channel Type: PI
Exposure Time: 8627 sec
Using fit statistic: cstat
Using test statistic: chi
Using Response (RMF) File ah100044010_sgd1_ccALL.rsp for Source 1

Spectral data counts: 17715
Model predicted rate: 0.0

Spectrum 3 Spectral Data File: ah100044010sg1_p0ccALLrec_dtime.pi
Net count rate (cts/s) for Spectrum:3 3.637e+00 +/- 2.732e-02
Assigned to Data Group 3 and Plot Group 3
Noticed Channels: 42-2048
Telescope: HITOMI Instrument: SGD1 Channel Type: PI
Exposure Time: 4871 sec
Using fit statistic: cstat
Using test statistic: chi
Using Response (RMF) File ah100044010_sgd1_ccALL.rsp for Source 1

Spectral data counts: 17715
Model predicted rate: 0.0

```

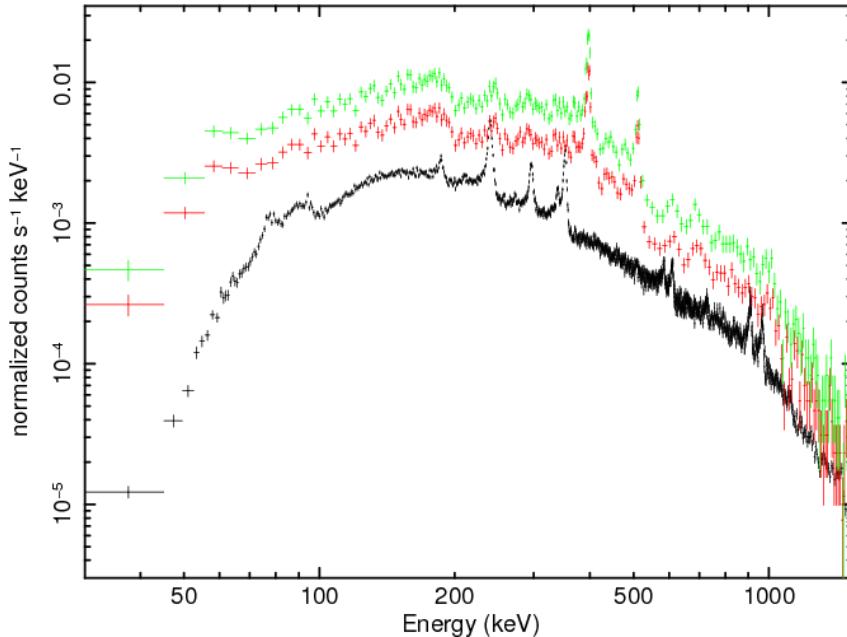


Figure 30: Comparison of NXB file in CALDB (black) with deadtime-corrected (green) and deadtime-uncorrected (red) spectra for SGD1 Crab nebula sequence 100044010.

(1) Fit the SXI 1 spectrum in the 0.8-12 keV band with a power-law model, with absorption free using the RMF, ARF, and background files created in the previous section:

```
1 file 1 spectrum
Spectrum 1  Spectral Data File: ah100044010sxi_p0112004e0_c1.pi
Net count rate (cts/s) for Spectrum:1  2.109e+03 +/- 4.612e+00
Assigned to Data Group 1 and Plot Group 1
Noticed Channels: 135-1999
Telescope: HITOMI Instrument: SXI Channel Type: PI
Exposure Time: 99.13 sec
Using fit statistic: cstat
Using test statistic: chi
Using Response (RMF) File      ah100044010sxi_p0112004e0_c1.rmf for
Source 1
Using Auxiliary Response (ARF) File ah100044010sxi_p0112004e0_rt.arf

Spectral data counts: 209053
Model predicted rate: 2108.80
```

Current model list:

```
=====
Model TBabs<1>*pegpwrlw<2> Source No.: 1 Active/On
Model Model Component Parameter Unit Value
par comp
 1   1   TBabs      nH       10^22    0.532612    +/-  5.92075E-03
 2   2   pegpwrlw  PhoIndex        2.05988    +/-  6.17353E-03
 3   2   pegpwrlw  eMin      keV     2.00000    frozen
 4   2   pegpwrlw  eMax      keV     10.0000    frozen
 5   2   pegpwrlw  norm          2.03803E+04  +/-  70.2400
```

Using energies from responses.

Fit statistic : C-Statistic = 2196.13 using 1865 PHA bins and 1862 degrees of freedom.

Test statistic : Chi-Squared = 2514.57 using 1865 PHA bins.
Reduced chi-squared = 1.35047 for 1862 degrees of freedom
Null hypothesis probability = 2.206777e-22

***Warning: Chi-square may not be valid due to bins with zero variance
in spectrum number(s): 1

Weighting method: standard

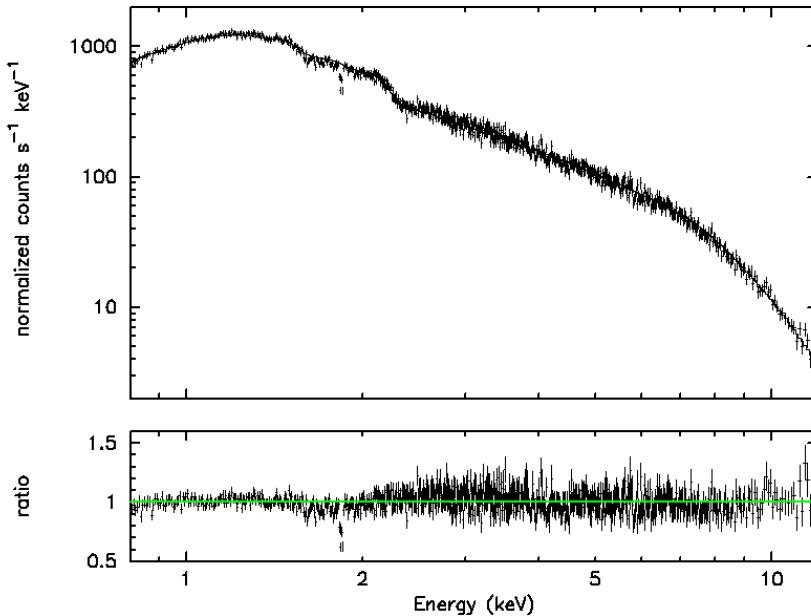


Figure 31: Spectral fits to SXI Normal mode Crab sequence 100044010 using the RMF and ARF files derived in the previous section. The 2-10 keV unabsorbed flux is 2.0×10^{-8} erg cm $^{-2}$ s $^{-1}$ in the best-fit model.

SXS

(1) Fit the SXS spectrum in the 1-12 keV band with a power-law model, with absorption 3.0×10^{21} cm $^{-2}$ using the xlarge RMF and ARF file created in the previous section:

```

1 file 1 spectrum
Spectrum 1  Spectral Data File: ah100044010sxs_p0px1010_c12_HMP.pi
Net count rate (cts/s) for Spectrum:1  5.980e+01 +/- 8.529e-02
Assigned to Data Group 1 and Plot Group 1
Noticed Channels: 1201-23999
Telescope: HITOMI Instrument: SXS Channel Type: PI
Exposure Time: 8219 sec
Using fit statistic: cstat
Using test statistic: chi
Using Response (RMF) File           ah100044010_sxs_c12_HMP_xlarge.rmf for
Source 1
Using Auxiliary Response (ARF) File ah100044010sxs_p0px1010_rt.arf

Spectral data counts: 491478
Model predicted rate: 59.7961

```

Current model list:

```

=====
Model TBabs<1>*pegpwrlw<2> Source No.: 1 Active/On
Model Model Component Parameter Unit      Value
par comp
 1    1    TBabs      nH        10^22     0.300000    frozen
 2    2    pegpwrlw   PhoIndex          2.17890    +/- 3.83958E-03
 3    2    pegpwrlw   eMin       keV      2.00000    frozen
 4    2    pegpwrlw   eMax       keV      10.0000    frozen
 5    2    pegpwrlw   norm          1.93224E+04 +/- 28.6612
=====
```

Using energies from responses.

```
Fit statistic : C-Statistic =      24729.59 using 22799 PHA bins and 22797
degrees of freedom.
```

```
Test statistic : Chi-Squared =      28023.86 using 22799 PHA bins.
Reduced chi-squared =      1.2229278 for 22797 degrees of freedom
Null hypothesis probability = 1.234275e-115
```

```
***Warning: Chi-square may not be valid due to bins with zero variance
in spectrum number(s): 1
```

Weighting method: standard

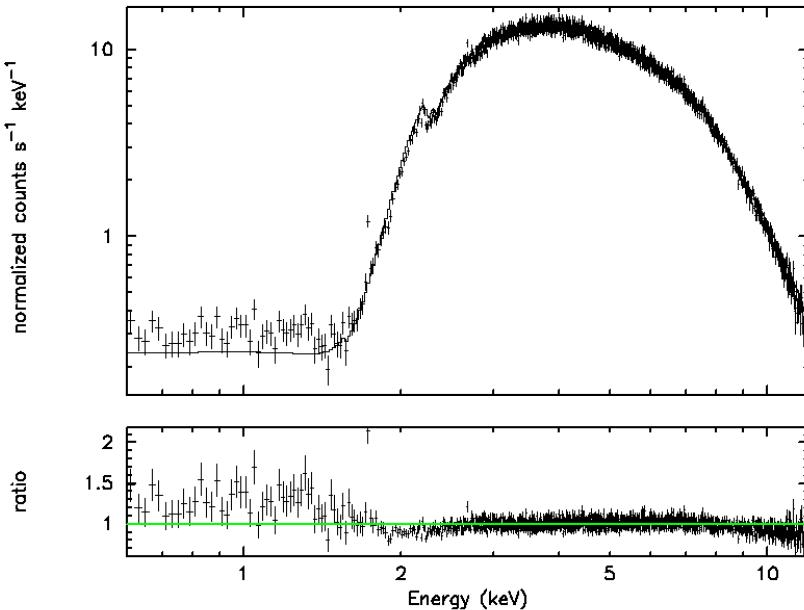


Figure 32: Fits to SXS spectra for Crab nebukl sequence 100044010 in the 0.6-12 keV band using the xlarge-sized RMF file. The 2-10 keV unabsorbed flux is 1.93×10^{-8} erg cm $^{-2}$ s $^{-1}$ in the best-fit model.

JOINT Spectra

- 1) Plot the HXI1 and HXI2 spectra in the 5-40 keV band, the SGD1 spectrum in the 30-2000 keV band, the SXI spectrum in the 0.8-12 keV band, and the SXS spectrum in the 0.6-12 keV band and the global spectral model from Kirsch et al. 2005 (SPIE, 5898, 22-33):

```
5 files 5 spectra
Spectrum 1  Spectral Data File: ah100044010hx1_p0camrec_dtime.pi
Net count rate (cts/s) for Spectrum:1  4.041e+02 +/- 2.613e-01
Assigned to Data Group 1 and Plot Group 1
Noticed Channels:  51-399
Telescope: HITOMI Instrument: HXI1  Channel Type: PI
Exposure Time: 5918 sec
Using fit statistic: cstat
Using test statistic: chi
Using Response (RMF) File          ah100044010hx1_rt.rsp for Source 1

Spectral data counts: 2.39121e+06
Model predicted rate: 384.111

Spectrum 2  Spectral Data File: ah100044010hx2_p0camrec_dtime.pi
```

```

Net count rate (cts/s) for Spectrum:2 3.556e+02 +/- 2.406e-01
Assigned to Data Group 2 and Plot Group 2
Noticed Channels: 51-399
Telescope: HITOMI Instrument: HXI2 Channel Type: PI
Exposure Time: 6141 sec
Using fit statistic: cstat
Using test statistic: chi
Using Response (RMF) File ah100044010hx2_rt.rsp for Source 1

Spectral data counts: 2.18368e+06
Model predicted rate: 373.866

Spectrum 3 Spectral Data File: ah100044010sg1_p0ccALLrec_dtime.pi
Net count rate (cts/s) for Spectrum:3 3.637e+00 +/- 2.732e-02
Assigned to Data Group 3 and Plot Group 3
Noticed Channels: 42-2048
Telescope: HITOMI Instrument: SGD1 Channel Type: PI
Exposure Time: 4871 sec
Using fit statistic: cstat
Using test statistic: chi
Using Response (RMF) File ah100044010_sgd1_ccALL.rsp for Source 1

Spectral data counts: 17715
Model predicted rate: 0.580731

Spectrum 4 Spectral Data File: ah100044010sxi_p0112004e0_cl_all.pi
Net count rate (cts/s) for Spectrum:4 2.109e+03 +/- 4.612e+00
Assigned to Data Group 4 and Plot Group 4
Noticed Channels: 135-1999
Telescope: HITOMI Instrument: SXI Channel Type: PI
Exposure Time: 99.13 sec
Using fit statistic: cstat
Using test statistic: chi
Using Response (RMF) File ah100044010sxi_p0112004e0_cl_all.rmf for
Source 1
Using Auxiliary Response (ARF) File ah100044010sxi_p0112004e0_rtALL.arf

Spectral data counts: 209053
Model predicted rate: 2284.73

Spectrum 5 Spectral Data File: ah100044010sxs_p0px1010_c12_HPMP.pi
Net count rate (cts/s) for Spectrum:5 5.980e+01 +/- 8.529e-02
Assigned to Data Group 5 and Plot Group 5
Noticed Channels: 1201-23999
Telescope: HITOMI Instrument: SXS Channel Type: PI
Exposure Time: 8219 sec
Using fit statistic: cstat
Using test statistic: chi
Using Response (RMF) File ah100044010_sxs_c12_HPMP_xlarge.rmf for
Source 1
Using Auxiliary Response (ARF) File ah100044010sxs_p0px1010_rt.arf

Spectral data counts: 491478
Model predicted rate: 63.7707

```

Current model list:

```
=====
Model phabs<1>*powerlaw<2> Source No.: 1 Active/On
Model Model Component Parameter Unit Value
par comp
Data group: 1
 1   1   phabs      nH      10^22    0.450000    +/-  0.0
 2   2   powerlaw   PhoIndex          2.08000    +/-  0.0
```

3	2	powerlaw	norm		8.97000	+/-	0.0
Data group: 2							
4	1	phabs	nH	10^{22}	0.450000	= p1	
5	2	powerlaw	PhoIndex		2.08000	= p2	
6	2	powerlaw	norm		8.97000	= p3	
Data group: 3							
7	1	phabs	nH	10^{22}	0.450000	= p1	
8	2	powerlaw	PhoIndex		2.08000	= p2	
9	2	powerlaw	norm		8.97000	= p3	
Data group: 4							
10	1	phabs	nH	10^{22}	0.450000	= p1	
11	2	powerlaw	PhoIndex		2.08000	= p2	
12	2	powerlaw	norm		8.97000	= p3	
Data group: 5							
13	1	phabs	nH	10^{22}	0.450000	= p1	
14	2	powerlaw	PhoIndex		2.08000	= p2	
15	2	powerlaw	norm		8.97000	= p3	

Using energies from responses.

Fit statistic : C-Statistic = 122260.8 using 27369 PHA bins and 27366 degrees of freedom.

Test statistic : Chi-Squared = 75204.39 using 27369 PHA bins.
 Reduced chi-squared = 2.748096 for 27366 degrees of freedom
 Null hypothesis probability = 0.0000000e+00

***Warning: Chi-square may not be valid due to bins with zero variance
 in spectrum number(s): 3 4 5

Current data and model not fit yet.

Weighting method: standard

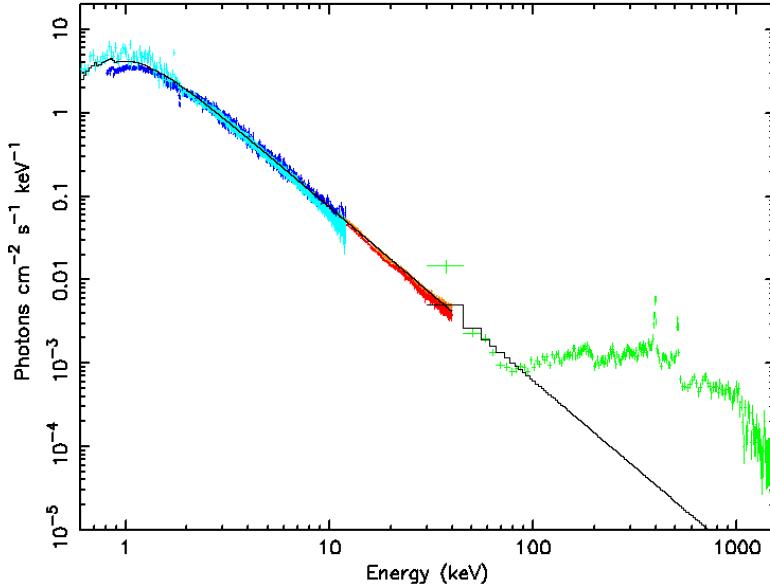


Figure 33: Unfolded spectra from all detectors (orange: HXI1, red: HXI2, green: SGD1, blue: SXI, light blue: SXS, black: model) using the broadband model from Kirsch et al. (2005; black).

(2) Fit the HXI1 and HXI2 spectra in the 5-40 keV band, the SXI spectrum in the 0.8-12 keV band, and the SXS spectrum in the 0.6-12 keV band with a power-law model with index untied, and with absorption free, using the xlarge SXS RMF and ARF files created in the previous section:

```

4 files 4 spectra
Spectrum 1 Spectral Data File: ah100044010hx1_p0camrec_dtime.pi
Net count rate (cts/s) for Spectrum:1 4.041e+02 +/- 2.613e-01
Assigned to Data Group 1 and Plot Group 1
Noticed Channels: 51-399
Telescope: HITOMI Instrument: HXII Channel Type: PI
Exposure Time: 5918 sec
Using fit statistic: cstat
Using test statistic: chi
Using Response (RMF) File           ah100044010hx1_rt.rsp for Source 1

Spectral data counts: 2.39121e+06
Model predicted rate: 400.802

Spectrum 2 Spectral Data File: ah100044010hx2_p0camrec_dtime.pi
Net count rate (cts/s) for Spectrum:2 3.556e+02 +/- 2.406e-01
Assigned to Data Group 2 and Plot Group 2
Noticed Channels: 51-399
Telescope: HITOMI Instrument: HXII Channel Type: PI
Exposure Time: 6141 sec
Using fit statistic: cstat
Using test statistic: chi
Using Response (RMF) File           ah100044010hx2_rt.rsp for Source 1

Spectral data counts: 2.18368e+06
Model predicted rate: 358.761

Spectrum 3 Spectral Data File: ah100044010sxi_p0112004e0_cl_all.pi
Net count rate (cts/s) for Spectrum:3 2.109e+03 +/- 4.612e+00
Assigned to Data Group 3 and Plot Group 3
Noticed Channels: 135-1999
Telescope: HITOMI Instrument: SXI Channel Type: PI
Exposure Time: 99.13 sec
Using fit statistic: cstat
Using test statistic: chi
Using Response (RMF) File           ah100044010sxi_p0112004e0_cl_all.rmf for
Source 1
Using Auxiliary Response (ARF) File ah100044010sxi_p0112004e0_rtALL.arf

Spectral data counts: 209053
Model predicted rate: 2108.80

Spectrum 4 Spectral Data File: ah100044010sxs_p0px1010_cl2_HPMP.pi
Net count rate (cts/s) for Spectrum:4 5.980e+01 +/- 8.529e-02
Assigned to Data Group 4 and Plot Group 4
Noticed Channels: 1201-23999
Telescope: HITOMI Instrument: SXS Channel Type: PI
Exposure Time: 8219 sec
Using fit statistic: cstat
Using test statistic: chi
Using Response (RMF) File           ah100044010_sxs_cl2_HPMP_xlarge.rmf for
Source 1
Using Auxiliary Response (ARF) File ah100044010sxs_p0px1010_rt.arf

Spectral data counts: 491478
Model predicted rate: 59.7961

```

Current model list:

```
=====
Model TBabs<1>*pegpwrlw<2> Source No.: 1 Active/On
Model Model Component Parameter Unit      Value
par comp
```

```

Data group: 1
1 1 TBabs nH 10^22 0.539822 +/- 5.88424E-03
2 2 pegpwrlw PhoIndex 2.11196 +/- 1.26086E-03
3 2 pegpwrlw eMin keV 2.00000 frozen
4 2 pegpwrlw eMax keV 10.0000 frozen
5 2 pegpwrlw norm 2.19592E+04 +/- 21.4871

Data group: 2
6 1 TBabs nH 10^22 0.539822 = p1
7 2 pegpwrlw PhoIndex 2.22174 +/- 1.24974E-03
8 2 pegpwrlw eMin keV 2.00000 = p3
9 2 pegpwrlw eMax keV 10.0000 = p4
10 2 pegpwrlw norm 2.19592E+04 = p5

Data group: 3
11 1 TBabs nH 10^22 0.539822 = p1
12 2 pegpwrlw PhoIndex 2.06598 +/- 6.14766E-03
13 2 pegpwrlw eMin keV 2.00000 = p3
14 2 pegpwrlw eMax keV 10.0000 = p4
15 2 pegpwrlw norm 2.03751E+04 +/- 70.1380

Data group: 4
16 1 TBabs nH 10^22 0.539822 = p1
17 2 pegpwrlw PhoIndex 2.20528 +/- 3.89511E-03
18 2 pegpwrlw eMin keV 2.00000 = p3
19 2 pegpwrlw eMax keV 10.0000 = p4
20 2 pegpwrlw norm 1.95981E+04 +/- 29.9718

```

Using energies from responses.

Fit statistic : C-Statistic = 30039.87 using 25362 PHA bins and 25354 degrees of freedom.

Test statistic : Chi-Squared = 33322.59 using 25362 PHA bins.
 Reduced chi-squared = 1.314293 for 25354 degrees of freedom
 Null hypothesis probability = 2.270874e-228

***Warning: Chi-square may not be valid due to bins with zero variance
 in spectrum number(s): 3 4

Weighting method: standard

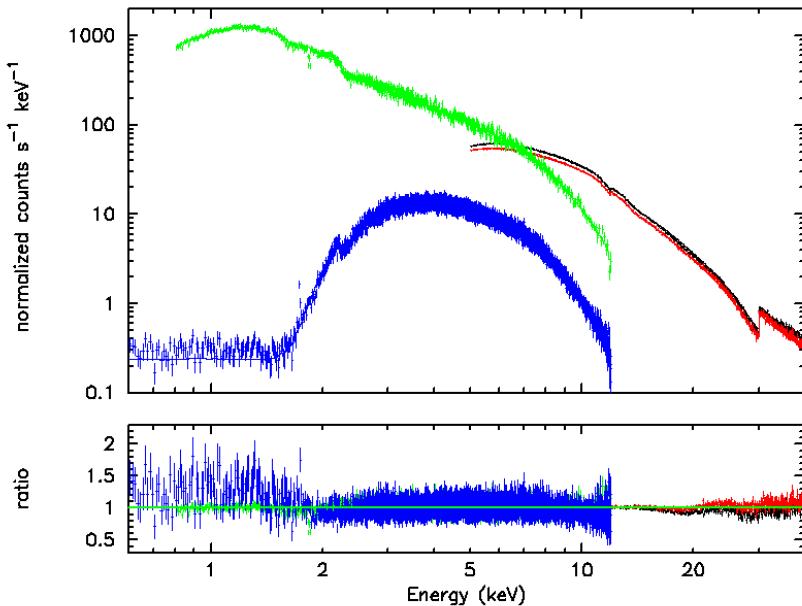


Figure 34: Fits to SXS Crab nebula sequence 100044010 spectra from all detectors (black: HXI1, red: HXI2, green: SXI, blue: SXS) with a power-law model with index untied, and with absorption free.

N132D

Table 5	100041010
GEN-HK	ah100041010gen_a0.hk1.gz
TIM	ah100041010.tim.gz
ATTITUDE	ah100041010.att.gz
ORBIT	ah100041010.orb.gz
OBSGTI	ah100041010_gen.gti.gz
MKF	ah100041010.mkf.gz
EHK	ah100041010.ehk.gz
EHK2	ah100041010.ehk2.gz
SXI HK	ah100041010sxi_a0.hk.gz
SXI EVT UF	ah100041010sxi_p010000360_uf.evt.gz ah100041010sxi_p1100003f0_uf.evt.gz ah100041010sxi_p2100003f0_uf.evt.gz ah100041010sxi_p3100003f0_uf.evt.gz ah100041010sxi_s010000360_uf.evt.gz
SXI MZDYE EVT UF	None
SXI HOTPIX	ah100041010sxi_a010000360.hpix.gz ah100041010sxi_a0100003f0.hpix.gz
SXI MZDYE HOTPIX	None
SXI FLICKPIX	ah100041010sxi_a010000360.fpix.gz ah100041010sxi_a1100003f0.fpix.gz ah100041010sxi_a2100003f0.fpix.gz ah100041010sxi_a3100003f0.fpix.gz
SXI MZDYE FLICKPIX	None
SXI BAD PIXEL IMG	ah100041010sxi_p010000360.bimg.gz ah100041010sxi_p1100003f0.bimg.gz ah100041010sxi_p2100003f0.bimg.gz ah100041010sxi_p3100003f0.bimg.gz
SXI MZDYE BAD PIXEL IMG	None
SXI TEL	ah100041010sxi_tel.gti.gz
SXI EVT CL	ah100041010sxi_p1100003f0_cl.evt.gz
SXI MZDYE EVT CL	None
SXS HK	ah100041010sxs_a0.hk1.gz
SXS ADR	ahsxs_adr.gti.gz
SXS AC EVT	ah100041010sxs_a0ac_uf.evt.gz
SXS PIX12 GAIN	ah100041010sxs_010_pxcal.ghf.gz
SXS PIX12 EVT	ah100041010sxs_a0pxcal010_uf.evt.gz
SXS EL GTI	ah100041010sxs_el.gti.gz
SXS TEL	ah100041010sxs_tel.gti.gz
SXS PIX GTI	ah100041010sxs_p0px1010.gti.gz
SXS PIX EXP	ah100041010sxs_p0px1010_exp.gti.gz
SXS PIX UF	ah100041010sxs_p0px1010_uf.evt.gz
SXS PIX CL	ah100041010sxs_p0px1010_cl.evt.gz

Table 5	100041020
GEN-HK	ah100041020gen_a0.hk1.gz
TIM	ah100041020.tim.gz
ATTITUDE	ah100041020.att.gz
ORBIT	ah100041020.orb.gz
OBSGTI	ah100041020_gen.gti.gz
MKF	ah100041020.mkf.gz
EHK	ah100041020.ehk.gz
EHK2	ah100041020.ehk2.gz
SXI HK	ah100041020sxi_a0.hk.gz
SXI EVT UF	ah100041020sxi_p1100003f0_uf.evt.gz ah100041020sxi_p2100003f0_uf.evt.gz ah100041020sxi_p3100003f0_uf.evt.gz ah100041020sxi_p4100003f0_uf.evt.gz ah100041020sxi_p5100003f0_uf.evt.gz ah100041020sxi_p6100003f0_uf.evt.gz ah100041020sxi_p7100003f0_uf.evt.gz ah100041020sxi_p8100003f0_uf.evt.gz ah100041020sxi_p9100003f0_uf.evt.gz
SXI MZDYE EVT UF	None
SXI HOTPIX	ah100041020sxi_a0100003f0.hpix.gz
SXI MZDYE HOTPIX	None
SXI FLICKPIX	ah100041020sxi_a1100003f0.fpix.gz ah100041020sxi_a2100003f0.fpix.gz ah100041020sxi_a3100003f0.fpix.gz ah100041020sxi_a4100003f0.fpix.gz ah100041020sxi_a5100003f0.fpix.gz ah100041020sxi_a6100003f0.fpix.gz ah100041020sxi_a7100003f0.fpix.gz ah100041020sxi_a8100003f0.fpix.gz ah100041020sxi_a9100003f0.fpix.gz
SXI MZDYE FLICKPIX	None
SXI BAD PIXEL IMG	ah100041020sxi_p1100003f0.bimg.gz ah100041020sxi_p2100003f0.bimg.gz ah100041020sxi_p3100003f0.bimg.gz ah100041020sxi_p4100003f0.bimg.gz ah100041020sxi_p5100003f0.bimg.gz ah100041020sxi_p6100003f0.bimg.gz ah100041020sxi_p7100003f0.bimg.gz ah100041020sxi_p8100003f0.bimg.gz ah100041020sxi_p9100003f0.bimg.gz
SXI MZDYE BAD PIXEL IMG	None
SXI TEL	ah100041020sxi_tel.gti.gz
SXI EVT CL	ah100041020sxi_p1100003f0_cl.evt.gz ah100041020sxi_p2100003f0_cl.evt.gz ah100041020sxi_p3100003f0_cl.evt.gz ah100041020sxi_p4100003f0_cl.evt.gz ah100041020sxi_p6100003f0_cl.evt.gz ah100041020sxi_p7100003f0_cl.evt.gz ah100041020sxi_p8100003f0_cl.evt.gz ah100041020sxi_p9100003f0_cl.evt.gz
SXI MZDYE EVT CL	None
SXS HK	ah100041020sxs_a0.hk1.gz
SXS ADR	ahsxs_adr.gti.gz
SXS AC EVT	ah100041020sxs_a0ac_uf.evt.gz
SXS PIX12 GAIN	ah100041020sxs_010_pxcal.ghf.gz
SXS PIX12 EVT	ah100041020sxs_a0pxcal010_uf.evt.gz
SXS EL GTI	ah100041020sxs_el.gti.gz
SXS TEL	ah100041020sxs_tel.gti.gz
SXS PIX GTI	ah100041020sxs_p0px1010.gti.gz
SXS PIX EXP	ah100041020sxs_p0px1010_exp.gti.gz
SXS PIX UF	ah100041020sxs_p0px1010_uf.evt.gz
SXS PIX CL	ah100041020sxs_p0px1010_cl.evt.gz

a) Untar in a directory /full/path/to/data/.

Additional text files for analysis are as follows, and are shown in detail as they are used.

- standard (and other) extraction region files (place in dir /full/path/to/regions)
 - n132d_SXS_det.reg
 - n132d_SXI_sky.reg
 - n132d_SXI_bkg.reg
- Lists of SXI files to input into addascaspec
 - merge_file.lis

NOTE on source regions files:

- i) 1.4 arcmin circle (SKY coordinates) for SXI source region
- ii) large annulus for which off-axis angle is nearly consistent with that of the source, for SXI background region
- iii) Full array (except pixel 12) for SXS (expressed in DET coordinates)

The region centers are determined by estimating the SKY coordinates of the source in the SXI image, and not on the expected source coordinates.

Note on sequences.

In sequence 100041010, STT emergency occurred, which resulted in only ~2 ksec exposure in the cleaned event data. We focus on the SXS data analysis for this sequence.

In sequence 100041020, because of the wrong attitude setting (STT problem), the source was observed off-axis during the entire observation. As the result, SXS did not detect any photons from the source. Thus we focus on the SXI analysis for this sequence.

Instrument Specific Reprocessing

100041010

SXS

(1) Recalibrate and rescreen using sxspipeline

```
sxspipeline indir=100041010 outdir=repro_100041010 steminputs=ah100041010
stemoutputs=ah100041010 entry_stage=1
attitude=100041010/auxil/ah100041010.att.gz
extended_housekeeping=100041010/auxil/ah100041010.ehk.gz
makefilter=100041010/auxil/ah100041010.mkf.gz
orbit=100041010/auxil/ah100041010.orb.gz
obsgti=100041010/auxil/ah100041010_gen.gti.gz
housekeeping=100041010/sxi/hk/ah100041010sxi_a0.hk.gz
timfile=100041010/auxil/ah100041010.tim.gz clobber=yes
```

100041020

SXI

(1) Recalibrate and rescreen using sxipipeline

```
sxipipeline indir=100041020 outdir=repro_100041020 steminputs=ah100041020  
stemoutputs=ah100041020 entry_stage=1 exit_stage=2  
attitude=100041020/auxil/ah100041020.att.gz  
extended_housekeeping=100041020/auxil/ah100041020.ehk.gz  
makefilter=100041020/auxil/ah100041020.mkf.gz  
orbit=100041020/auxil/ah100041020.orb.gz  
obsgti=100041020/auxil/ah100041020_gen.gti.gz  
housekeeping=100041020/sxi/hk/ah100041020sxi_a0.hk.gz clobber=yes
```

Extracting Products

This section details tools to run on cleaned event files to get instrument specific data products. These may be applied to the original cleaned event files from the pipeline, or to new cleaned event files created using the steps in the last section. In what follows, the reprocessed cleaned event files are used. The extraction region files described above are assumed to be in the `regions` directory.

100041010

SXS

All necessary input files and newly created output files in this section are placed in the `/full/path/to/data/sxi_products` directory

```
cd /full/path/  
cd data/products_sxs
```

(1) Additional screening

Create a “cleaned-2” SXS event file

```
ah100041010sxs_p0px1010_c12.evt
```

by applying a RISETIME cut to Hp, Mp, Ms, and Lp (but not Ls) events.

```
ftselect infile=ah100041010sxs_p0px1010_c1.evt \  
outfile=ah100041010sxs_p0px1010_c12.evt \  
expression="(PI>=400)&&((RISE_TIME>=40 && RISE_TIME<=60 &&  
ITYPE<4) || (ITYPE==4))"
```

(2) Extract source spectra and light curves using xselect

```
xselect  
xsel  
xsel> read eve ah100041010sxs_p0px1010_c12.evt  
xsel> ./  
xsel> yes  
xsel:HIOTMI-SXS-PX_NORMAL > set xyname detx dety  
xsel:HIOTMI-SXS-PX_NORMAL > bin all
```

```

xsel:HIOTMI-SXS-PX_NORMAL > save image image_100041010sxs.fits
xsel:HIOTMI-SXS-PX_NORMAL > save spec spec_100041010sxs.pi
xsel:HIOTMI-SXS-PX_NORMAL > exit

```

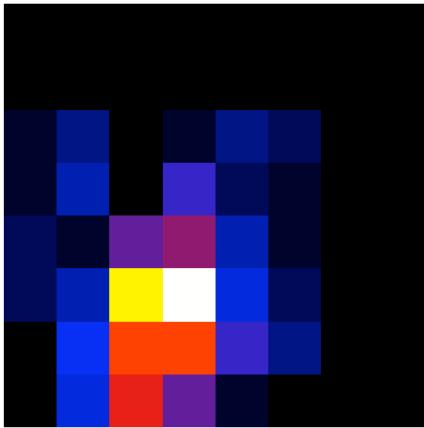


Figure 35: SXS image for sequence 100041010 in DET coordinate.

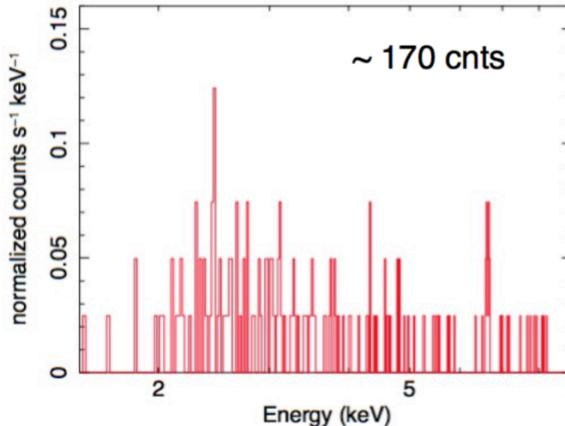


Figure 36: SXS spectrum for sequence 100041010.

100041020

SXI

All necessary input files and newly created output files in this section are placed in the /full/path/to/data/sxi_products directory.

```

cd /full/path/
cd data/products_sxi

```

There are nine cleaned SXI event files for this sequence:

```

ah100041020sxi_p1100003f0_cl.evt
ah100041020sxi_p2100003f0_cl.evt
ah100041020sxi_p3100003f0_cl.evt
ah100041020sxi_p4100003f0_cl.evt
ah100041020sxi_p6100003f0_cl.evt

```

```

ah100041020sxi_p7100003f0_cl.evt
ah100041020sxi_p8100003f0_cl.evt
ah100041020sxi_p9100003f0_cl.evt

```

Due to differences in the number of bad pixels (because of time dependent cosmic-ray-echo effect) between OBSIDs, the SXI event data cannot be combined in the same way as the other instruments. Instead, spectra, RMFs, exposure maps, and ARFs must be generated for each OBSID separately and then simultaneously combined at the end (see next section).

The content of the source region file used here, `.../regions/n132d_SXI_sky.reg`, which excludes the central 30 arcsec to reduce pileup effects, is

```

# Region file format: DS9 version 4.1
global color=green dashlist=8 3 width=1 font="helvetica 10 normal roman" select=1
highlite=1 dash=0 fixed=0 edit=1 move=1 delete=1 include=1 source=1
fk5
circle(5:25:03.845,-69:38:36.15,83.6655) # width=2
-box(5:25:19.760,-69:38:30.96,84.3775",176.884",356.668) # width=2

```

and the background region used here, `.../regions/n132d_SXI_bkg.reg`,

```

# Region file format: DS9 version 4.1
global color=green dashlist=8 3 width=1 font="helvetica 10 normal roman" select=1
highlite=1 dash=0 fixed=0 edit=1 move=1 delete=1 include=1 source=1
fk5
circle(5:26:01.000,-69:43:48.00,570")
-circle(5:25:03.845,-69:38:36.15,300.9")
-box(5:25:23.875,-69:50:27.78,63",443.62",356.668)
-circle(5:26:01.000,-69:43:48.00,300")
-box(5:27:10.289,-69:39:57.37,397.534",63",356)

```

(1) Extract images, source spectra, and light curves using xselect

```

xselect
xsel
xsel:SUZAKU > read eve ah100041020sxi_p1100003f0_cl.evt
./
yes
xsel:HITOMI-SXI-WINDOW1 > filter region n132d_SXI_sky.reg
xsel:HITOMI-SXI-WINDOW1 > bin all
xsel:HITOMI-SXI-WINDOW1 > save spec spec_p1100003f0_src.pi
xsel:HITOMI-SXI-WINDOW1 > clear region
xsel:HITOMI-SXI-WINDOW1 > filter region n132d_SXI_bkg.reg
xsel:HITOMI-SXI-WINDOW1 > bin all
xsel:HITOMI-SXI-WINDOW1 > save spec spec_p1100003f0_bkg.pi
xsel:HITOMI-SXI-WINDOW1 > exit

```

Repeat this process for all eight cleaned event files.

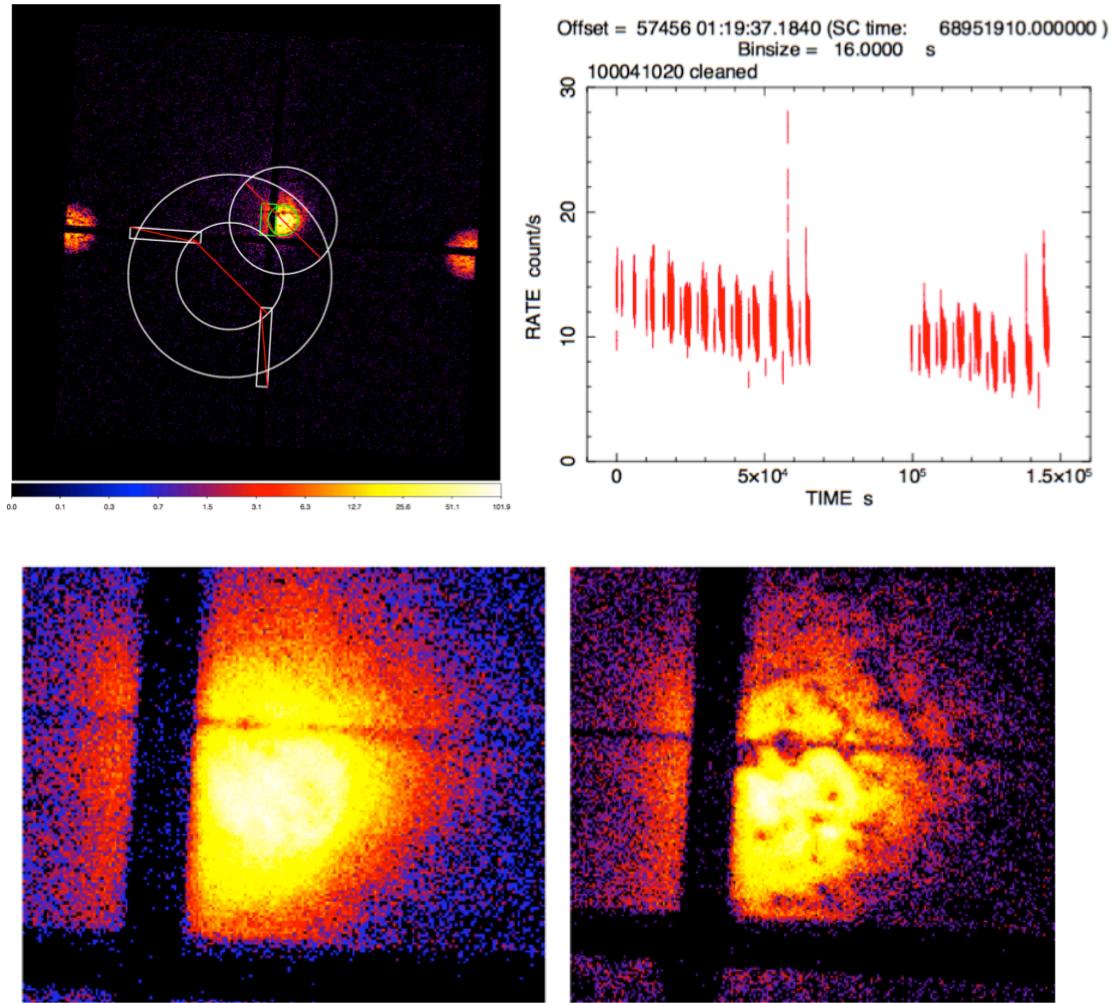


Figure 37: Top – SXI image (with extraction regions) and lightcurves for sequence 100041020. The count rate gradually decreases because the number of CR echo pixels increases with time (see below for more details). Bottom – Close-up images around the source including and excluding the CR-echo pixels.

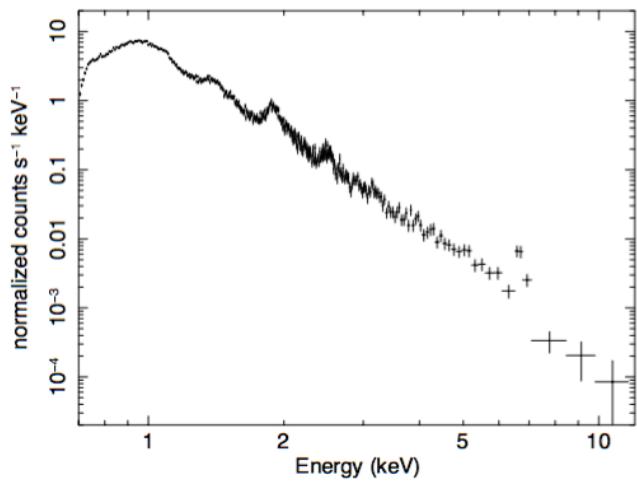


Figure 38: SXI spectrum for sequence 100041010 .

Generating Exposure Map, RMF, and ARF

100041010

SXS

(1) Generate the RMF

Here we use the “medium” size option (Gaussian and exponential tail). Change whichrmf parameter to “l” to include escape peaks, but it is not really needed given the low statistics in this data. The all-pixel DET coordinate region file n132d_sxs_det.reg that may be created by sxsregext is input:

```
physical
+box(4,1,5,1.00000000)
+box(3.5,2,6,1.00000000)
+box(3.5,3,6,1.00000000)
+box(3.5,4,6,1.00000000)
+box(3.5,5,6,1.00000000)
+box(3.5,6,6,1.00000000)

sxsmkrmf infile=ah100041010sxs_p0px1010_c12.evt outfile=resp_100041010sxs.rmf
resolist=ALL regmode=DET regionfile=n132d_SXS_det.reg whichrmf=M
```

Alternatively, an identical rmf file can be created (by using pixlist option) without the region file.

```
sxsmkrmf infile=ah100041010sxs_p0px1010_c12.evt outfile=resp_100041010sxs.rmf
resolist=ALL regmode=DET regionfile=NONE whichrmf=M pixlist="0-11,13-35"
```

(2) Generate the SXS exposure maps

```
ahexpmap ehkfile=../100041010/auxil/ah100041010.ehk.gz
gtifile=ah100041010sxs_p0px1010_c12.evt instrume=SXS badimgfile=None
pixgtifile=../100041010/sxs/event_uf/ah100041010sxs_px1010_exp.gti.gz
outfile=ah100041010sxs_p0px1010.expo outmaptype=EXPOSURE delta=20.0 numphi=1 \
clobber=yes
```

3) Generate the SXS ARF

```
aharfgen xrtevtfile=raytrace_ah100041010sxs_p0px1010.fitssource_ra=81.26
source_dec=-69.63497 telescop=HITOMI instrume=SXS
emapfile=ah100041010sxs_p0px1010.expo regmode=DET regionfile=n132d_SXS_det.reg
sourcetype=POINT rmffile=resp_100041010sxs.rmf erange="0.6 15.0 0 0"
outfile=arf_100041010sxs.arf numphoton=100000 minphoton=1 teldeffile=CALDB
qefile=CALDB contamofile=CALDB obffile=CALDB fwfile=CALDB gatevalvefile=CALDB
onaxisffile=CALDB onaxisccfile=CALDB mirrorfile=CALDB obstructfile=CALDB
frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB
dattfile=none filtoffsetfile=none sampling=4 imgfile=none clobber=yes
```

Note that the source_ra and source_dec are estimated based on the SXI image.

100041020

SXI

Note that because the cosmic ray echo effect varies between sequences over the course of the observation, a single bad image file cannot be used below. In general this should be checked when deriving SXI spectral ARFs for combined sequences. If they differ as they do here, separate RMF and ARF files should be derived for each OBSID. The spectra and responses should then be co-added, or individual spectra should be simultaneously fit.

```
cd /full/path/
```

```
cd data/products_sxi
```

(1) Create an RMF for each sequence

```
sxirmf infile=spec_p1100003f0_src.pi outfile=resp_p1100003f0_src.rmf
sxirmf infile=spec_p2100003f0_src.pi outfile=resp_p2100003f0_src.rmf
sxirmf infile=spec_p3100003f0_src.pi outfile=resp_p3100003f0_src.rmf
sxirmf infile=spec_p4100003f0_src.pi outfile=resp_p4100003f0_src.rmf
sxirmf infile=spec_p6100003f0_src.pi outfile=resp_p6100003f0_src.rmf
sxirmf infile=spec_p7100003f0_src.pi outfile=resp_p7100003f0_src.rmf
sxirmf infile=spec_p8100003f0_src.pi outfile=resp_p8100003f0_src.rmf
sxirmf infile=spec_p9100003f0_src.pi outfile=resp_p9100003f0_src.rmf
```

(2) Create an exposure map for each sequence

```
ahexpmap ehkfile=../100041020/auxil/ah100041020.ehk.gz
gtifile='ah100041020sxi_p1100003f0_cl.evt[2]' instrume=SXI
badimgfile=ah100041020sxi_p1100003f0.bimg
pixgtifile=ah100041020sxi_a1100003f0.fpix
outfile=ah100041020sxi_p1100003f0.expo outmapttype=EXPOSURE delta=2 numphi=1
clobber=yes
```

```
ahexpmap ehkfile=../100041020/auxil/ah100041020.ehk.gz
gtifile='ah100041020sxi_p2100003f0_cl.evt[2]' instrume=SXI
badimgfile=ah100041020sxi_p2100003f0.bimg
pixgtifile=ah100041020sxi_a2100003f0.fpix
outfile=ah100041020sxi_p2100003f0.expo outmapttype=EXPOSURE delta=2 numphi=1
clobber=yes
```

```
ahexpmap ehkfile=../100041020/auxil/ah100041020.ehk.gz
gtifile='ah100041020sxi_p3100003f0_cl.evt[2]' instrume=SXI
badimgfile=ah100041020sxi_p3100003f0.bimg
pixgtifile=ah100041020sxi_a3100003f0.fpix
outfile=ah100041020sxi_p3100003f0.expo outmapttype=EXPOSURE delta=2 numphi=1
clobber=yes
```

```
ahexpmap ehkfile=../100041020/auxil/ah100041020.ehk.gz
gtifile='ah100041020sxi_p4100003f0_cl.evt[2]' instrume=SXI
badimgfile=ah100041020sxi_p4100003f0.bimg
pixgtifile=ah100041020sxi_a4100003f0.fpix
outfile=ah100041020sxi_p4100003f0.expo outmapttype=EXPOSURE delta=2 numphi=1
clobber=yes
```

```
ahexpmap ehkfile=../100041020/auxil/ah100041020.ehk.gz
gtifile='ah100041020sxi_p5100003f0_cl.evt[2]' instrume=SXI
badimgfile=ah100041020sxi_p5100003f0.bimg
pixgtifile=ah100041020sxi_a5100003f0.fpix
outfile=ah100041020sxi_p5100003f0.expo outmapttype=EXPOSURE delta=2 numphi=1
clobber=yes
```

```
ahexpmap ehkfile=../100041020/auxil/ah100041020.ehk.gz
gtifile='ah100041020sxi_p6100003f0_cl.evt[2]' instrume=SXI
badimgfile=ah100041020sxi_p6100003f0.bimg
pixgtifile=ah100041020sxi_a6100003f0.fpix
```

```

outfile=ah100041020sxi_p6100003f0.expo outmaptype=EXPOSURE delta=2 numphi=1
clobber=yes

ahexpmap ehkfile=../100041020/auxil/ah100041020.ehk.gz
gtifile='ah100041020sxi_p7100003f0_cl.evt[2]' instrume=SXI
badimgfile=ah100041020sxi_p7100003f0.bimg
pixgtifile=ah100041020sxi_a7100003f0.fpix
outfile=ah100041020sxi_p7100003f0.expo outmaptype=EXPOSURE delta=2 numphi=1
clobber=yes

ahexpmap ehkfile=../100041020/auxil/ah100041020.ehk.gz
gtifile='ah100041020sxi_p8100003f0_cl.evt[2]' instrume=SXI
badimgfile=ah100041020sxi_p8100003f0.bimg
pixgtifile=ah100041020sxi_a8100003f0.fpix
outfile=ah100041020sxi_p8100003f0.expo outmaptype=EXPOSURE delta=2 numphi=1
clobber=yes

ahexpmap ehkfile=../100041020/auxil/ah100041020.ehk.gz
gtifile='ah100041020sxi_p9100003f0_cl.evt[2]' instrume=SXI
badimgfile=ah100041020sxi_p9100003f0.bimg
pixgtifile=ah100041020sxi_a9100003f0.fpix
outfile=ah100041020sxi_p9100003f0.expo outmaptype=EXPOSURE delta=2 numphi=1
clobber=yes

```

(3) Create an ARF for each spectrum

```

aharfgen xrtevtfile=xrtraytrace_p1100003f0.fits source_ra=81.26 source_dec=
69.63497 telescop=HITOMI instrume=SXI regmode=SKY regionfile=n132d_SXI_sky.reg
sourcetype=POINT outfile=arf_p1100003f0_src.arf
emapfile=ah100041020sxi_p1100003f0.expo rmffile=resp_p1100003f0_src.rmf
numphoton=100000 minphoton=1 erange="0.6 15.0" teldeffile=CALDB qefile=CALDB
contamofile=CALDB obffile=CALDB fwfile=CALDB gatevalvefile=CALDB
onaxisffile=CALDB onaxiscfle=CALDB mirrorfile=CALDB obstructfile=CALDB
frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB
dattfile=none filtoffsetfile=none sampling=4 imgfile=none clobber=yes

aharfgen xrtevtfile=xrtraytrace_p2100003f0.fits source_ra=81.26 source_dec=
69.63497 telescop=HITOMI instrume=SXI regmode=SKY regionfile=n132d_SXI_sky.reg
sourcetype=POINT outfile=arf_p2100003f0_src.arf
emapfile=ah100041020sxi_p2100003f0.expo rmffile=resp_p2100003f0_src.rmf
numphoton=100000 minphoton=1 erange="0.6 15.0" teldeffile=CALDB qefile=CALDB
contamofile=CALDB obffile=CALDB fwfile=CALDB gatevalvefile=CALDB
onaxisffile=CALDB onaxiscfle=CALDB mirrorfile=CALDB obstructfile=CALDB
frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB
dattfile=none filtoffsetfile=none sampling=4 imgfile=none clobber=yes

aharfgen xrtevtfile=xrtraytrace_p3100003f0.fits source_ra=81.26 source_dec=
69.63497 telescop=HITOMI instrume=SXI regmode=SKY regionfile=n132d_SXI_sky.reg
sourcetype=POINT outfile=arf_p3100003f0_src.arf
emapfile=ah100041020sxi_p3100003f0.expo rmffile=resp_p3100003f0_src.rmf
numphoton=100000 minphoton=1 erange="0.6 15.0" teldeffile=CALDB qefile=CALDB
contamofile=CALDB obffile=CALDB fwfile=CALDB gatevalvefile=CALDB
onaxisffile=CALDB onaxiscfle=CALDB mirrorfile=CALDB obstructfile=CALDB
frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB
dattfile=none filtoffsetfile=none sampling=4 imgfile=none clobber=yes

aharfgen xrtevtfile=xrtraytrace_p4100003f0.fits source_ra=81.26 source_dec=
69.63497 telescop=HITOMI instrume=SXI regmode=SKY regionfile=n132d_SXI_sky.reg
sourcetype=POINT outfile=arf_p4100003f0_src.arf
emapfile=ah100041020sxi_p4100003f0.expo rmffile=resp_p4100003f0_src.rmf
numphoton=100000 minphoton=1 erange="0.6 15.0" teldeffile=CALDB qefile=CALDB
contamofile=CALDB obffile=CALDB fwfile=CALDB gatevalvefile=CALDB
onaxisffile=CALDB onaxiscfle=CALDB mirrorfile=CALDB obstructfile=CALDB

```

```

frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB
dattfile=none filtoffsetfile=none sampling=4 imgfile=none clobber=yes

aharfgen xrtevtfile=xrtraytrace_p5100003f0.fits source_ra=81.26 source_dec=
69.63497 telescop=HITOMI instrume=SXI regmode=SKY regionfile=n132d_SXI_sky.reg
sourcetype=POINT outfile=arf_p5100003f0_src.arf
emapfile=ah100041020sxi_p5100003f0.expo rmffile=resp_p5100003f0_src.rmf
numphoton=100000 minphoton=1 erange="0.6 15.0" teldeffile=CALDB qefile=CALDB
contamofile=CALDB obffile=CALDB fwfile=CALDB gatevalvefile=CALDB
onaxisffile=CALDB onaxiscfille=CALDB mirrorfile=CALDB obstructfile=CALDB
frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB
dattfile=none filtoffsetfile=none sampling=4 imgfile=none clobber=yes

aharfgen xrtevtfile=xrtraytrace_p6100003f0.fits source_ra=81.26 source_dec=
69.63497 telescop=HITOMI instrume=SXI regmode=SKY regionfile=n132d_SXI_sky.reg
sourcetype=POINT outfile=arf_p6100003f0_src.arf
emapfile=ah100041020sxi_p6100003f0.expo rmffile=resp_p6100003f0_src.rmf
numphoton=100000 minphoton=1 erange="0.6 15.0" teldeffile=CALDB qefile=CALDB
contamofile=CALDB obffile=CALDB fwfile=CALDB gatevalvefile=CALDB
onaxisffile=CALDB onaxiscfille=CALDB mirrorfile=CALDB obstructfile=CALDB
frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB
dattfile=none filtoffsetfile=none sampling=4 imgfile=none clobber=yes

aharfgen xrtevtfile=xrtraytrace_p7100003f0.fits source_ra=81.26 source_dec=
69.63497 telescop=HITOMI instrume=SXI regmode=SKY regionfile=n132d_SXI_sky.reg
sourcetype=POINT outfile=arf_p7100003f0_src.arf
emapfile=ah100041020sxi_p7100003f0.expo rmffile=resp_p7100003f0_src.rmf
numphoton=100000 minphoton=1 erange="0.6 15.0" teldeffile=CALDB qefile=CALDB
contamofile=CALDB obffile=CALDB fwfile=CALDB gatevalvefile=CALDB
onaxisffile=CALDB onaxiscfille=CALDB mirrorfile=CALDB obstructfile=CALDB
frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB
dattfile=none filtoffsetfile=none sampling=4 imgfile=none clobber=yes

aharfgen xrtevtfile=xrtraytrace_p8100003f0.fits source_ra=81.26 source_dec=
69.63497 telescop=HITOMI instrume=SXI regmode=SKY regionfile=n132d_SXI_sky.reg
sourcetype=POINT outfile=arf_p8100003f0_src.arf
emapfile=ah100041020sxi_p8100003f0.expo rmffile=resp_p8100003f0_src.rmf
numphoton=100000 minphoton=1 erange="0.6 15.0" teldeffile=CALDB qefile=CALDB
contamofile=CALDB obffile=CALDB fwfile=CALDB gatevalvefile=CALDB
onaxisffile=CALDB onaxiscfille=CALDB mirrorfile=CALDB obstructfile=CALDB
frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB
dattfile=none filtoffsetfile=none sampling=4 imgfile=none clobber=yes

aharfgen xrtevtfile=xrtraytrace_p9100003f0.fits source_ra=81.26 source_dec=
69.63497 telescop=HITOMI instrume=SXI regmode=SKY regionfile=n132d_SXI_sky.reg
sourcetype=POINT outfile=arf_p9100003f0_src.arf
emapfile=ah100041020sxi_p9100003f0.expo rmffile=resp_p9100003f0_src.rmf
numphoton=100000 minphoton=1 erange="0.6 15.0" teldeffile=CALDB qefile=CALDB
contamofile=CALDB obffile=CALDB fwfile=CALDB gatevalvefile=CALDB
onaxisffile=CALDB onaxiscfille=CALDB mirrorfile=CALDB obstructfile=CALDB
frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB
dattfile=none filtoffsetfile=none sampling=4 imgfile=none clobber=yes

```

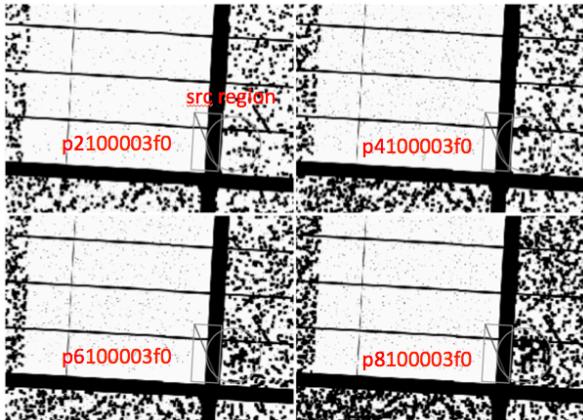


Figure 39: Resulting exposure maps for different subsequences. The number of bad pixels (mostly due to CR echo) is significantly different among them.

(5) Correct the BACKSCAL keyword in the SXI spectra

Run the script given below on all 16 source and background pi files. These steps are applied by hand for the Perseus and G21.5-0.9 sequence above.

```
fix_backscal.sh spec_p1100003f0_src.pi ah100041020sxi_p1100003f0.expo
n132d_SXI_sky.reg
```

```
fix_backscal.sh spec_p1100003f0_bkg.pi ah100041020sxi_p1100003f0.expo
n132d_SXI_bkg.reg
```

The contents of the script "fix_backscal.sh" is following.

```
#!/bin/bash

# fix_backscal.sh -- script to properly calculate BACKSCAL from the
# extraction region file and exposure map for SXI spectra. Assumes the
# extraction region and exposure map are in SKY coordinates.
# HEASOFT must be initialized before running this.

read -r help<<EOH
usage: fix_backscal.sh <spectrum> <exposure_map> <region_file>
EOH

if [ $# -ne 3 ] ; then
    echo "$help"
    exit
fi

specfile=$1
expofile=$2
regfile=$3

tmp_xcofile="fix_backscal.xco"
sxi_size=2430

# Read the exposure map into XIMAGE and use the "counts" command to
# obtain the number of pixel*seconds within the region.

echo "read/rebin=1/szx=${sxi_size}/szy=${sxi_size} ${expofile}" >| $tmp_xcofile
echo "counts ${regfile}" >> $tmp_xcofile
tot_pixsec=`ximage < $tmp_xcofile | tail -3 | awk '{print $2}'`
```

```

/bin/rm $tmp_xcofile

# Get the good exposure time from the exposure map.

fkeypar ${expofile}[1] EXPOSURE
texp=`pget fkeypar value` 

# Divide "Total counts" reported by XIMAGE by the exposure time to get
# the total number of good pixels. Note that it is fractional, because
# some of the pixels in SKY coordinates have fractional exposure due to
# even small attitude wobbles (e.g., that location on the sky moves in and
# out of a bad pixel or charge injection row).

num_goodpix=`echo $tot_pixsec $texp | awk '{print $1/$2}'` 

# Divide the number of good pixels by the total number of pixels in X,Y
# coordinates (2430x2430).

backscal=`echo $num_goodpix $ssi_size | awk '{print $1/($2)**2}'` 

# Update the spectrum header with the new BACKSCAL.

fkeypar ${specfile}[1] BACKSCAL
old_backscal=`pget fkeypar value` 
fthedit ${specfile}[1] BACKSCAL a $backscal

echo "Spectrum file $specfile has been updated."
echo "Old BACKSCAL is $old_backscal"
echo "New BACKSCAL is $backscal"

exit

```

(5) Combine SXI spectra and responses

The ftool ‘addascaspec’ should be used to combine the source spectra, background spectra, and responses.

```
addascaspec merge_file.list spec_merged_src.pi resp_merged_src.rsp
spec_merged_bkg.pi gauss
```

where the file ‘merge_file.list’ contains the following four lines (delineated by ‘\’):

```

spec_p1100003f0_src.pi spec_p2100003f0_src.pi spec_p3100003f0_src.pi
spec_p4100003f0_src.pi spec_p6100003f0_src.pi spec_p7100003f0_src.pi
spec_p8100003f0_src.pi spec_p9100003f0_src.pi \
spec_p1100003f0_bkg.pi spec_p2100003f0_bkg.pi spec_p3100003f0_bkg.pi
spec_p4100003f0_bkg.pi spec_p6100003f0_bkg.pi spec_p7100003f0_bkg.pi
spec_p8100003f0_bkg.pi spec_p9100003f0_bkg.pi \
arf_p1100003f0_src.arf arf_p2100003f0_src.arf arf_p3100003f0_src.arf
arf_p4100003f0_src.arf arf_p6100003f0_src.arf arf_p7100003f0_src.arf
arf_p8100003f0_src.arf arf_p9100003f0_src.arf \
resp_p1100003f0_src.rmf resp_p2100003f0_src.rmf resp_p3100003f0_src.rmf
resp_p4100003f0_src.rmf resp_p6100003f0_src.rmf resp_p7100003f0_src.rmf
resp_p8100003f0_src.rmf resp_p9100003f0_src.rmf

```

This will create a combined source spectrum, combined background spectrum, and a single .rsp file containing both the combined RMF and ARF.